GEOGRAPHY OF LIVING THINGS

M. S. ANDERSON

THE TEACH YOURSELF BOOKS
EDITED BY LEONARD CUTTS

GEOGRAPHY OF LIVING THINGS

in the
GEOGRAPHY
Section

Prepared under the special
direction and scientific
Editorship of

PROFESSOR FRANK DEBENHAM
Cambridge University

TEACH YOURSELF GEOGRAPHY

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THE USE OF GEOGRAPHY
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HISTORICAL GEOGRAPHY
by J. B. Mitchell

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By

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A GENERAL INTRODUCTION TO THE SERIES

In planning a series of volumes to be called *Teach Yourself Geography*, it was necessary for me, as Editor, to choose between alternatives, and I want you to understand why I made the decision I did and what we have set out to do.

It would have been possible to adopt the delightful, and very successful, method used by the English Universities Press historians, who present each volume in their series as the story of a period based upon the life of a great man. Our geography series might well have had the pattern of a Place and its People for each book until the world was covered. The result would have been a new series of Regional Geographies which, though useful, would have been mainly descriptive in character and not fundamental to the subject. They would have been a loose pile of stones rather than a masonry structure keyed together to make a building.

Now, geography was described by one of its greatest recent exponents as not so much a subject as a point of view. With that in mind, I decided it was better to take the other alternative: to lead readers to the top of the mountain whence they could get that view, rather than just give them a series of peeps at individual parts of the landscape.

In my key volume, I set out to provide the incentive for that climb, outlining the route and giving a general idea of the prospect at the summit. The title of the book is *The Use of Geography*, and if interest, contentment and an increased power of judgment are sufficient rewards, then geography is useful indeed. You will find I have dealt mainly with the structure of the subject and its aims, with hints as to the ways and means of achieving some part of it: an understanding of Place in all its bearings. My chief object was to show that geography is for everyone, and that it is full of interest at every stage, and that it is a practical subject.

The four companion volumes concern themselves more closely with technique—if such a formidable word can be used

to describe the approach to each of the divisions into which geography can be conveniently separated for the purpose of study.

Thus Mr. Peel's book deals with the physical background; those aspects of air, land and water which, quite independently of man, affect the environment in which we live, and which are almost, but not quite, beyond our control. He points the way towards learning about the inanimate world around us, and his treatment of this branch of the subject is as thorough as the length of the book will permit.

Mrs. Anderson in her *Geography of Living Things* deals with the animate side of environment, culminating in the highest of the animals, Man himself. In some ways she is opening up a new development of Geography, or at least a new focussing point, for you will find that she emphasises the biological influences which constantly affect man for good or ill and which have in large measure determined where and how he lives; why he varies so much in appearance, and even in character. Her vivid style is well suited to such a fresh viewpoint. If this book is a study of man as an animal living under essentially the same biological controls as other animals, then Mr. Thatcher leads us to consider man as a highly organised social being with trade between places and peoples as a dominating control.

He calls his book *Economic Geography*, "an experiment." Each of these volumes is an experiment—and certainly if it is an experiment to take an apparently intricate subject like this and reduce it to a lively simplicity by talking to his reader as he might at his own fireside, then we could do with many more such experiments. Even such a forbidding subject as the Mechanism of Exchange can become absorbing when chatted about by a kindly tutor possessed of a cheerful pessimism and an infinite understanding. The case for Economic Geography rests very safely in his hands.

Finally, the geographer must look back as well as forward if he is to study fully the interaction between Place and Man. The geographies of the past are in some respects the most powerful influences which mould the geography of the present. Miss Mitchell deals in a scholarly way with these in her *Historical Geography*. Because it is a new line of approach she has to spend some time in explaining what it is and is not. The

rewards are great, for when rightly understood there is something peculiarly fascinating in tracing the Past in the Present, in viewing Place, whether on parish- or country-scale, as determined very largely by what has happened before. This volume should put Historical Geography very firmly on its feet as an integral part of the subject as a whole and one which any reader can share in and profit by.

Lastly, I should like to explain that this series is a combined effort. One of the reasons for selecting the authors from my own staff was so that we could work together as a team. Yet even frequent consultation is not in itself sufficient to achieve agreement and a common point of view, and it is as much the personality of my authors as their knowledge that is responsible for the unity we hope will appear in the separate volumes of this series. I am, in fact, proud to introduce to the general reader these members of a staff who have made my duty easy not only as Editor, but in the more arduous capacity of running the large department of which they form a part.

FRANK DEBENHAM

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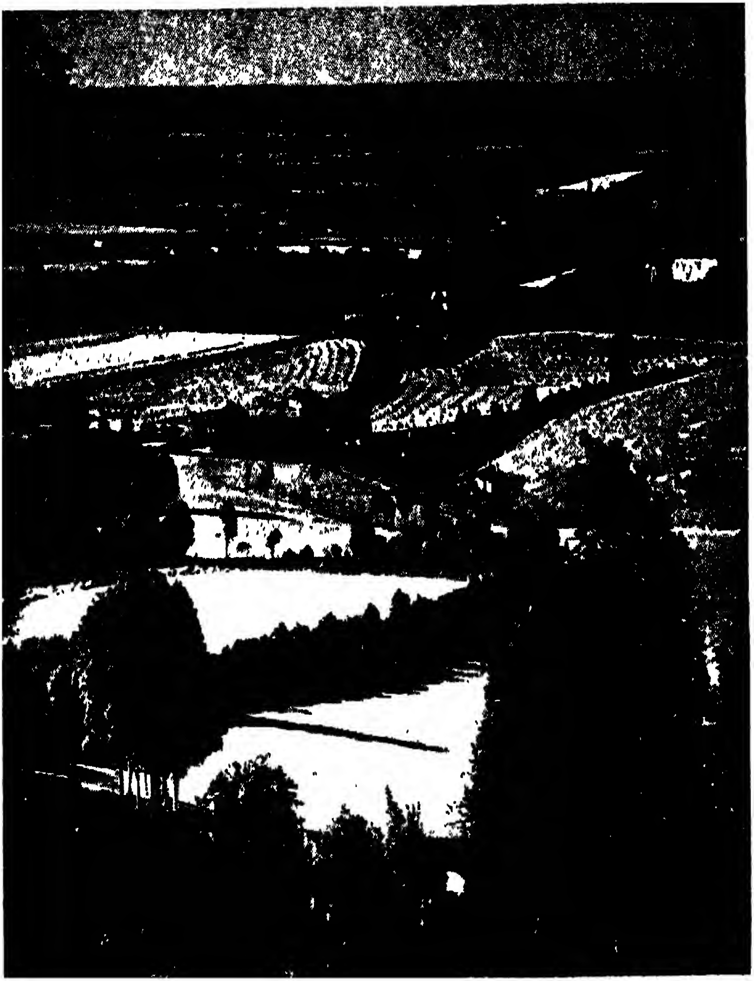


[Photo: Ronald Goodearl.

A WELL INTEGRATED LANDSCAPE

CHAPTER I

WHAT THIS BOOK IS ABOUT

THE study with which this book deals is the branch of Geography that connects the physical side of the subject with the human side, and it is convenient to call it Biogeography. In Physical Geography we study the phenomena of the earth's surface—weather and climate, oceans and seas, rocks, the form of the land, rivers, glaciers, deserts and volcanoes: in Human Geography we study man's relations to all these things, the way that he is distributed over the earth, and the ways in which he uses for his own ends the natural resources that he finds to hand in his surroundings or "environment." In this series the book on Physical Geography deals with the non-living part of the environment, the books on Economic Geography and on Historical Geography with two of the many specialised branches of general Human Geography. In this book on Biogeography we shall study some of the more important links, particularly the biological links, between these two sides of Geography.

In text-books of Human Geography much attention is generally paid to certain features of the environment—geographical position, topography, climate and so on—as factors moulding the distribution and activities of mankind. Any living beings, present in the environment, whether plants or animals, are all too often looked upon in much the same way as the dead physical features of the landscape, as material ready to man's hand to use as he sees fit. Similarly, in much modern political writing, the earth with all its living inhabitants is tacitly regarded as if it were a lifeless, passive medium, clay in the hands of man the potter, submissively waiting for him to mould it to his own ends exactly as seems best to him. It is implied that, although the environment may influence man's activities by providing him with raw materials or presenting him with problems whose

solution affects his own welfare, it can neither direct nor control his activities: since he is such a superbly intelligent being he is independent of nature, and is free to use the materials she provides and solve the problems she sets him in any ways he pleases, limited only by his innate ability, the techniques at his disposal, and the traditions he lives by. Bemused by the vastness of his scientific knowledge and technical skill, and by the apparently complete mastery which he has attained over physical and chemical processes, man often forgets that nevertheless he is still just an animal, with all the physical and biological limitations that that fact implies.

To the Biogeographer such an anthropocentric view of the relations between ourselves and the earth we live on appears not merely erroneous but dangerously so. Along with all the other living inhabitants of the earth, we are subject not only to the physical and chemical laws so thoroughly explored by modern science but also to biological laws. In spite of our wide understanding of physical and chemical laws and our mastery of physical and chemical processes, we still understand comparatively little about biological laws, and our control over biological processes is very slight. We can split atoms, fly faster than sound, and talk familiarly to our friends half a world away, but we can neither live without plants to feed us, nor choose the sex of our children, nor even control on the large scale the rate at which our numbers shall increase. These are all matters of transcendent importance not only in our individual lives but in the survival and welfare of the human species as a whole, determining to a great extent its success in the struggle for existence. Yet we have not attained anything approaching the technical skill and understanding in these matters that we have attained in the physical sciences, and many of our present world problems stem from that fact: at present we can do no more than conform blindly to biological laws, and if we attempt to evade their action we court disaster.

This is where Biogeography comes in, as it studies the particular biological laws which, since we are animals, tie us firmly,

to our physical environment. By the term "physical environment" I mean here more than simply the physical geography of our surroundings: I mean everything about us that we can touch or use or see, including not only obvious physical features such as the air we breathe, the water we drink and the land we dwell on, but also the living things that swarm about us in countless myriads, though most of them are far too small to be seen with the unaided eye—the plants that feed us, the animals we eat, the infinitesimal creatures that live and work in the soil, and the disease germs, pests and parasites that afflict, besides ourselves, our domestic animals and our crops. All these things help to make up our physical environment, as I shall use the term here, and we are linked to them in a multitude of ways. All these factors of the environment are physical, in the sense that they are concrete and measurable and subject to the usual physical and chemical laws, while the living ones are subject also to the biological laws that I have just mentioned. But the term "physical" excludes the many social and psychological factors in our environment, factors that are of enormous importance in many ways: these cannot be neglected in any reasoned attempt to understand the whole of any of our present-day problems, but they are outside the scope of Biogeography. As Biogeographers we may be directly concerned with, let us say, water supply and public health, but not directly with religion, politics, law or education. We study the relations between men and forests, or men and mosquitoes, but the relations between individual men or nations we leave to other studies except in so far as they directly affect our chosen field.

We are now in a position to define our subject. Biogeography is "the study of the biological relations between man, considered as an animal, and the whole of his animate and inanimate physical environment." These relations are governed by biological laws which can be studied by ordinary scientific methods, laws as inflexible as those of the physical sciences, although their existence is often ignored by planners and politicians: these laws define narrowly the limits within which we may alter or adapt

our physical environment to serve our own ends. They cannot be set aside at will; we have as yet hardly begun to learn how to use them for our own benefit; but we are obliged to obey them, and we shall thrive as a species only so long as we do so. They are the unbreakable bonds that tie us, however intellectually emancipated or technologically advanced we may be, to the soil, rocks, air, water, plants and animals that share this earth with us. Proposed solutions to our urgent and tragic modern problems, whether put forward by planners, by politicians or by economists, are foredoomed to failure if they flout these laws. These laws are the subject matter of Biogeography.

Of our physical environment much of the inanimate part is out of our power to control, though we may very considerably modify it. We can light and heat our rooms in winter but cannot appreciably alter the temperature of the outside air nor the length of the day; we can bring water in pipes from hundreds of miles away, but cannot appreciably increase the amount of rain that falls on our fields. All the factors commonly grouped together as climate—heat and cold, rain, wind, snow and hail, wayward, unpredictable and of enormous importance in our lives—are all part of our physical environment. So too is the ground on which we live: its shape, whether flat or hilly, in a hollow or on a ridge; its position, near the sea, in the dry interior of a vast continent, on the shady side of a mountain or on the fertile but hazardous slope of a volcano; and its make-up, whether thin hungry sands, cold heavy clay, or warm rich prairie loam. The rocks below the ground are important too; among other things they provide materials for building houses or for making tools and weapons, and they often determine whether we can trust to a permanent well or spring for our water or must rely on a capricious rainfall. All these things are parts of our physical environment, and the ways in which we react to them and use them is one part of our study.

Besides the inanimate part of our physical environment there is the living part of it: the soil underfoot with its teeming bacteria, fungi and earth-worms; the plants that not only grace

the landscape but help to generate the soil that covers it, and themselves provide an almost inexhaustible supply of food, raw materials and luxuries ; and the animals living in the air or the soil or the plants, millions upon millions of them—worms, insects, birds, mice, domestic creatures like cows and dogs ; wilder, less familiar, but often very important creatures such as foxes, which have given rise to a social microcosm as complete as a Trades Union, and rats, the indestructible and menacing reservoir of bubonic plague. All these are parts of our living physical environment ; with all of them we must learn to live, if not in a state of amity at least in one of armed truce. Some we can control, or believe we can : others, at certain times and in certain places control us ; are not the Kent potato farmers, bent double as they search their fields for the dreaded Colorado beetle, as much slaves to the beetle as the native porters of Central Africa are to the tsetse fly, which forbids them to keep animals to carry their loads for them ?

The Biogeographer is out to study our relations to all these living creatures that help to make up our physical environment, as well as the inter-relations between ourselves, these creatures and the features of the inanimate physical environment such as climate, position, water and soil. For he has set himself a task of immense importance and dignity, no less than to learn how we may one day get back into true harmony with the great dumb forces of nature that rule both us and the other live creatures that we must rely on to feed and serve us and to keep our crops healthy and abundant, so that there may be a perfect natural balance among us all, to the greater wellbeing of everyone. He looks to a future in which the world will hold, not ill-fed, diseased, quarrelsome, destructive nations greedily struggling to pull from the tree all the fruits that nature gives them, but a healthy, peaceful, truly humane body of mankind, living in harmony among themselves and with the wonderful, beautiful living things whose right also to live on the earth God gave them we shall have learnt to respect. This is the ultimate aim of the Biogeographer—to learn how we can live in harmony with the

whole of our physical environment; for only by such harmonious living shall we eventually cure many of the miseries that now afflict us, miseries that have their roots in faulty living and in a faulty relationship between ourselves and the earth our home. We have failed to recognise that we must live well as animals before we can live happily as men; we have devoted too much of our time and thought to the science of living in comfort and too little to the art of living well—which is by no means the same thing. I hope that in the course of this book it will become clear to you that by studying the natural laws that prevail among all living things we can learn much about the art of living, and that by submitting to those laws and working with nature instead of against her we may not only retain but may deserve the position of supremacy we now hold among living things.

This book is one of a series called the "Teach Yourself" Series, and before going any further I must try to make it quite clear what it is that you are going to teach yourself by reading it. You are not going to get from it just a collection of facts, though it will provide you with a few that you need to know. You are, I hope, going to get from it, in lieu of facts, an attitude of mind. When you have taught yourself this attitude of mind, and I hope that this book may a little help you to do so, you will no longer be able to look at anything in the world about you—a tree, a town, a road, a river—and think of it as simply itself, an individual distinct and separate from its surroundings. Whether living or dead, it is tied to everything else in its surroundings by the laws which I mentioned earlier in this chapter, physical, chemical, and above all biological. It is like a single cell of a living body, that body the whole landscape, immensely complex, evolved through time by who knows what tangle of causes and effects; it is like a cell in that it fulfils certain functions indispensable for maintaining the present condition of other cells of the body, and it quietly, irresistibly spreads around itself, like ripples on a pool, the inescapable consequences of its own existence.

When you begin to acquire this attitude of mind, when you

begin to see all separate things as parts of a whole and not simply as discrete individuals, everything about you begins to take on new meanings: the earth, the clouds, rivers and seas, plants and animals, and above all man himself, all have their parts to play in building up the landscape, and if we destroy or displace any least one of the individual cells that make it up the pattern of the whole changes, as the bubbles of a lather redistribute themselves when one bursts.

When you have achieved this habit of mind, characteristic of the Biogeographer, you will also see things, I hope, from a different and more objective viewpoint than you did before. You will think of a landscape as alive with plants and animals, not merely a dead scene of hills and rivers. You will look on a river, for example, neither entirely as a physical agent moulding the form of the valleys and plains through which it flows, nor solely as a possible source of water power, a highway for commerce, a route for settlers, a boundary, a unifying influence, though all these ways of looking at it are habitual with geographers and you will find them in other books in this Series; but you will look on it also as a stream of water, one of the first necessities of life, water for man, his cattle and his crops to drink: as a factor helping to determine the numbers of men that may live in its valley: as the home of fish and other shy wild creatures that feed man or pester him, and in open or hidden ways affect his life and his activities: and as being in its turn, like the human societies on its banks, in a state of perpetual flux, changed, shifted, varied by the very men whose lives and actions it so subtly but so deeply sways.

Let me take another concrete example to show what I mean by the attitude of mind of the Biogeographer. It is an example concerned with a very tiny piece of landscape, but the principles it illustrates may be applied to a whole river valley, a great city, a country, or any larger unit you please. You are sitting under a tree in a hedge on a June day, looking at a field of wheat in flower. What do you see?—sunshine, emptiness, a sea of waving shot-silk grass-stems, all peace and loneliness after the

stir and friction of a town? Or do you in your mind's eye look on the wheat solely as a good or a bad crop, likely to bring in so much profit at present prices? Or do you see the field, perhaps, as a potential building site, to accommodate the overcrowded slum-dwellers of the town? It may be all these things and more, but I hope that perhaps after reading this book you will think of the field of wheat also as food: see, in your imagination, walking through the waving stems, an army of hungry town-dwellers, cut off from the living earth by their pavements and house-walls, unable to grow food for themselves, *animals whose food that wheat is destined to become. You will see the neat rows of plants, all of one kind, as a change wrought by man in the natural landscape and maintained by him only through* a constant warfare against natural foes—birds, insects, fungi and other organisms—that like wheat for food as much as he himself does: as a change maintained only at the cost of continual watchfulness and unremitting labour, lest the field slip back into wilderness and fail to grow the food for that hungry invisible company. You will see the wheat as a crop chosen to suit the soil and climate and to fit in with the farming pattern of the district, and also as one which makes certain imperious demands on the soil it grows on, altering it, compelling the farmer in his turn to apply fertilisers and manures and to use crop rotations in order to keep the soil in good condition for his crops.

That tree you are sitting under—what part does it play? Its roots suck out from the soil foods that might have gone to swell the wheat; its boughs shade a patch of the crop; rabbits living in burrows among its roots have ruined a patch of wheat. Surely it would be better to fell the tree? It might fetch a little cash as timber or firewood. But what of the owls that nest in that hole in the trunk, and feed themselves and their young on the rats and mice that ravage the stored grain in the barns and stackyard and on the rabbits that nibble the young wheat? What of the welcome shade the tree gives to grazing cows when in the course of a long rotation the field is laid down to a grass ley? What of the shelter and nesting sites it affords for smaller birds

who eat the caterpillars that destroy the fruit in the nearby orchard? Fell the tree, and all these relationships are altered; it would take much wisdom to know whether the outcome would be for better or for worse. But the point I wish to make is that the tree is more than a mere source of timber: it has a definite part to play in the life of the field and the farm, and these in their turn have parts to play in the life of the whole district and of the whole country; if you are a good geographer you have always at the back of your mind a mental picture of all these functions performed by the component parts of a landscape whenever you look at one, however apparently dull or restricted it may be. The principles that I have applied above to the tree and the wheat apply just as well to larger units, a factory, a road, a pass, a town or a harbour. Every landscape is an expression of the relations that exist in that spot between the earth, the sun and rain, plants, animals and man: most of them express chiefly man's attempts to adapt the earth and its plants and animals to his own needs, and, to a lesser extent, his attempts to adapt himself and his way of life to his environment. His unceasing, kaleidoscopic, never entirely successful attempts to get what he wants from the earth without too far violating her laws form the subject matter of this book; the attitude of mind that you acquire by thinking of most of man's activities as such attempts is the one which is characteristic of the Biogeographer, and the one which I hope this book may enable you to teach yourself.

CHAPTER II

MAN AS AN ANIMAL

WE said in the last chapter that in Biogeography we study the biological laws that tie us to our physical environment. *It is by virtue of the fact that we are animals that we are subject to these laws. So before we can get much further with our study we must be quite clear what an animal is and what it does, and how it is related to the environment in which it lives.* In this chapter we shall begin by considering some of the fundamental characteristics of all animals which are relevant to our subject, the study of the relations existing between one particular animal, man, and his environment.

Many of the characteristics that distinguish animate from inanimate beings are shared alike by plants and animals. All living things, for instance, grow and develop, that is to say they increase in size and alter in structure. They do this by taking into themselves various substances which differ chemically from the living substance of which they are composed, termed "protoplasm." This ability to increase the amount of its own substance by taking in something not composed of that substance distinguishes living from non-living matter. A crystal can grow, but to do so it must take in more of the exact chemical of which it is already composed: a baby can grow, and build up more blood, muscle, liver, bones and brains by taking in nothing but milk. This whole complex set of activities, characteristic only of living things, is known as "metabolism." The substances taken in are altered in various ways: the living thing uses some parts of them and rejects others, and in this way obtains not only the raw materials for building up its own protoplasm but also the energy needed for its own growth, development and other activities.

Metabolic processes are of two main kinds. In "katabolic" processes, or *katabolism* (from a Greek word meaning to throw

down), the organism breaks down substances of complex chemical composition existing in its body, converting them into simpler chemical compounds, and by this process it obtains the energy it needs to grow, move, develop or reproduce. From our point of view the most important katabolic process is *Respiration*, a process found both in plants and in animals and fundamentally similar in both. In "anabolic" processes, or *anabolism* (from a word meaning to throw back), the organism builds up its body substance, as in growth, reproduction, repair of damaged tissues, replacement of substances lost in katabolism, or storage of food. From our point of view the most important anabolic process is *Nutrition*, a process which is profoundly different in plants and in animals and which indeed serves as a basis for separating the two groups.

Respiration and the need for oxygen.

In *Respiration*, the organism, whether plant or animal, takes in *oxygen*, from the supply freely available in nature, in the air, the water and the soil: it uses it to burn up, in the chemical sense, part of its food or its body substance, in much the same way that sugar or oil burns in the presence of the oxygen of the air, except that in metabolism the process goes on much more slowly. But chemically the process is exactly the same as burning, and the end products, whether of metabolism or of combustion, are the same: in the respiration of sugar, one of the commonest substances used for this purpose, they are carbon dioxide and water. In both metabolism and in burning, energy is given out: it appears as a hot flame in burning, but in metabolism most of it is used to provide some sort of chemical or mechanical work, although certain groups of animals such as ourselves do also give out appreciable amounts of heat as a result of our slow internal combustion in the process of respiration. The organism uses the energy it obtains from respiring the substances in its body to grow or develop, move about, or produce seeds or eggs or babies.

For respiration to go on, in most living things, a supply of

free oxygen is essential, and this is obtained from the air or water in which the creature lives, in other words from the physical environment. No living creatures except rather peculiar, very small ones, such as some kinds of bacteria, can live long without free oxygen : a man deprived of it dies in a few minutes. Luckily oxygen is abundant almost everywhere in the atmosphere, and it is so uniformly distributed over the globe that from the point of view of the geographer it is not very interesting as a factor influencing man's distribution or activities. It has never had to be rationed, nor do people have to go and live beside oxygen cylinders as they do by springs of water, and if you emigrate to Australia you can be certain that you will find the oxygen there exactly the same as it is at home, whereas the climate or the scenery or the food is not. But where oxygen does run short, as in very high mountains, there man cannot live at all, though he may pass through such regions in a "pressurized" air liner or struggle up into them for a few hours or days, at the cost of great difficulty and exhaustion. So oxygen for breathing, though one of the absolute essentials for the life of man as for other animals, is only interesting to the geographer where it begins to run out : elsewhere it is too ordinary and ubiquitous to affect the places and the ways in which men live. However the amount of oxygen available, where it is seriously different from the amount available at sea level, has certain clearly defined biological effects upon man and other animals, and so comes within the scope of Biogeography : we shall consider some of these effects in the next chapter.

Nutrition and the need for food.

In *Nutrition*, the organism takes in all sorts of substances existing around it in the environment and converts them into more of its own particular variety of protoplasm. The protoplasm of both plants and animals is alike in many ways but differs in detail, and from species to species. It contains much water, a fact to which we shall later pay more attention, but in addition it contains many substances which are chemically ex-

tremely complicated. They are called *organic* substances, a name originally given because it was supposed that they could only be produced by living organisms, in the days when the science of chemistry was not nearly so advanced as it is now. All these organic substances contain *carbon*, an element peculiar among the other elements in its capacity for forming innumerable different compounds containing very large numbers of atoms: there are far more compounds of carbon known than of all the other elements together. Besides carbon, organic substances contain *oxygen* and *hydrogen* as their principal constituents, but in addition they may contain smaller amounts of other elements, particularly *nitrogen*, *sulphur*, *phosphorus*, *calcium*, *iron*, *chlorine* and *potassium*, besides minute traces of many others such as *copper*, *zinc*, *iodine*, *fluorine* and *manganese*, whose functions in the living body are very much more important than the minute amounts in which they occur there would suggest.

All living creatures, which as we have seen are distinguished from non-living matter by the fact that they carry on metabolism, must in some way obtain from their physical environment all these elements, in the forms and proportions in which they can use them. It is this inescapable fact which is ultimately the most important of all the relations between man and the earth: it forms an unbreakable bond between them. It is the central fact of Biogeography, and the fundamental biological law with which we have to deal.

In the physical world of inorganic matter these elements essential for the metabolism of living organisms exist in great variety. Some occur free, that is to say they are not in chemical combination with any other element. Among these are the oxygen and nitrogen of the atmosphere. Others occur as simple compounds, whose molecules are built up from a few atoms only. These simple compounds include *water*, which occupies a very special place in our study because it enters largely into the composition of protoplasm, and because it is as essential to man as oxygen. Water is the universal solvent in which all other substances must be dissolved before they can be absorbed into

living protoplasm, and in a watery solution take place all the infinitely numerous and complex chemical reactions which make up the processes of metabolism. Water exists in the environment free but never pure; even recently-fallen raindrops contain dissolved gases such as oxygen and carbon dioxide. The soil water contains an enormous number of dissolved substances. Many of them are simple salts, such as chlorides, nitrates, sulphates and phosphates of metals such as calcium, magnesium, potassium, iron and so on; among them these contain most of the elements required by living protoplasm. Other inorganic compounds present in rain water and soil water are of rather more complex chemical composition, while many rocks and rock minerals present around us in the environment are so extremely complex in their molecular structure that, it appears, they cannot be used directly in the nutrition of either plants or animals. Only when these minerals have been broken down by the processes of chemical weathering (see book in this series on Physical Geography) to simpler inorganic substances are they of use in the nutrition of living things.

Even so, these supplies of uncombined elements and simple inorganic compounds, freely available in the environment, can be used in nutrition by no other living beings except—and it is a very important exception—green plants. In the presence of *chlorophyll*, the pigment to which these plants owe their colour, and of sunlight, which supplies the energy needed for carrying on the chemical reactions involved, living plants can build up, from water, the *carbon dioxide* of the air, and the simple salts which they absorb from the soil in very weak watery solution, organic compounds of highly complex chemical composition, such as sugars, starches, cellulose, lignin, fats, oils and proteins. This process is known as *photosynthesis*. It is by this process alone that an entity so vast and weighty as an oak tree or a Cedar of Lebanon can grow from a seed weighing no more than a button, building up iron-hard wood and a mighty spread of tough roots and branches out of the air and the water in the soil and nothing more. By virtue of this process a field of

potatoes is, from man's point of view, a starch factory, turning the free carbon dioxide from the air and the water from the soil into the excellent food that we never fully appreciated until it was rationed. A bean field is an equally efficient protein factory, using the same ubiquitous raw materials and also simple salts of nitric acid, dissolved in the soil water or helpfully manufactured in a subsidiary factory run by bacteria living in nodules on the beans' roots, to synthesise the somewhat cloying protein of the bean seeds, which vegetarians use as a substitute for meat.

Photosynthesis, then, is the mode of nutrition characteristic of all green plants; it is the synthesis, in the presence of chlorophyll and of sunlight, of complex organic compounds from simple inorganic ones existing free in the non-living physical environment. Since green plants thus need no help from any other living beings in order to nourish themselves, they are called *autotrophic*, or self-feeding.

Animals, on the other hand, cannot nourish themselves from simple inorganic compounds; they are said to be *heterotrophic*, or fed by others. This means that they depend for their nutrition on organic substances already synthesised either by plants or, at second-hand, by other animals. These organic substances are already chemically very complex. The animal *ingests* them, or takes them into its body by swallowing or otherwise: there it *digests* them, or attacks them with all sorts of digestive juices from hydrochloric acid to bile, so that they are partially broken down into slightly simpler compounds which are soluble in water, and in that form they can be absorbed by the protoplasm of the living cells of which the animal's body is composed. Here the raw materials provided by the partial chemical decomposition of the food are reunited and recombined to form the particular types of protoplasm or of stored food characteristic of that animal. Thus a rabbit, a goose and a cow may eat the same pasture, but when they have ingested, digested and absorbed the same proteins, cellulose and other constituents of the grasses, they respectively make out of the same raw materials rabbit flesh, goose eggs or milk. Each animal selects certain parts of the

food eaten during the processes of digestion and absorption, and builds these up into its own characteristic flesh and blood; each rejects other parts, in the same processes, and excretes them in the form of its own characteristic dung.

The animal is thus, unlike the plant, dependent for its *food*, without which it cannot continue to live, on other living things, in the final analysis on green plants. This is the fundamental difference between animals and plants: the plants synthesise complex organic compounds from simple inorganic ones; the animals merely reassort and metamorphose the complex organic compounds made by the plants. Or, more simply, it is the plants that make the foods; the animals eat them. Ask an animal—let us say a distinguished chemist—to live on some dilute solutions of carbon dioxide and a few simple salts: let him have all the chlorophyll and sunshine that he likes to ask for, and he will starve, even if he is the most brilliant and distinguished chemist in the world. But give him some living green plants to combine his simple chemicals for him into sugars, starches, fats or proteins, and he will be all right: his trouble lies in the fact that, being an animal, albeit a very clever one, he cannot make all the kinds of food that he needs to keep himself alive from nothing but simple gases and salts and water. It seems odd that when he has got his complicated food substances from the plants he has then got to change them back again into simpler ones before he can use them to build up into his muscles and bones and blood and brains, but then he does not have to change them right back into carbon dioxide and salts; he uses them before they get broken down so far, while they are still very complex substances such as glucose, which is a simpler sugar than cane-sugar, or amino-acids, which are the highly complex bricks from which the still more complex proteins are built up. Some of these substances we can already make in the laboratory.

The need for water.

The variety of foodstuffs on which man can subsist is so great, and their distribution is so extremely complicated, that we shall

later devote several chapters (Chapters V, VI and VII) to considering them in more detail. But we cannot leave the subject of metabolism, whether in plants or animals, without a further reference to *water*. The need for water is as universal in living things as the need for oxygen. A great but variable proportion of the volume of protoplasm is water; in the immortal phrase of Sir Arthur Shipley, "even the Archbishop of Canterbury comprises 59 per cent of water." Only a few creatures, for instance clothes-moths, can live permanently in an absolute drought and never need a drink: clothes-moths can make what little water they need out of dry things like wool, which is handy if you have to spend all your life in a wardrobe. A man can at most live about a week without drinking, though many vegetarian animals can get along very well without ever taking a real drink, since there is enough water in their food to keep them from drying up.

Now water is much more interesting to the geographer than oxygen; it is so peculiarly distributed, with far too much in some places and not enough in others. Also a lot of it is salt, much too salt for land animals to use for drinking. Moreover, it is cold and wet and has an extremely insecure surface, and man cannot use the oxygen dissolved in it for breathing. With all his ingenuity man has not yet taken to living on the oceans and seas, though the seas round the North Atlantic have a very small but fairly permanent population composed of the crews of lightships and weather ships, and the Channel has about the same number of people to the square mile as live in a square mile of Siberia, though in both places many of the people are engaged in trying to get as quickly as possible to somewhere else. On land, fresh water is most capriciously distributed, according to the climate, the lie of the land, the rocks underneath it, and so on. In his earlier days man had to go where the water was: nearly all the sites of older villages and towns are clearly related to the position of rivers, springs or wells. Modern man spends a prodigious amount of time and material in taking water away from its natural home and putting it somewhere else, because he wants

to live there and has got to have water to drink. The water supply, in fact, whether from rain or rivers or underground streams, is one of the most important parts of the physical environment, and we shall devote a good deal more space to a consideration of it and its effects on man's distribution and activities in Chapter IV.

Man, then, is an animal, and has the same physical needs as other animals, for oxygen, water and food. These things alone tie him very firmly to his environment, as we shall see in later chapters, and the distribution of natural sources of water, of pastures for the animals he eats, and of fertile land to grow plants for food, has had much to do with determining the present distribution and numbers of men on earth. These matters we shall return to in later chapters, but first there are one or two other things about man, considered simply as an animal, that are of interest to the Biogeographer.

Let us think first of his physical appearance and bodily structure, and put him into his proper scientific pigeonhole in the classification of the whole animal kingdom. His scientific name is *Homo sapiens*, which means that he is classed as belonging to one species—"sapiens," the wise one—of the genus Homo, a genus which at present holds man only, though it may have included at least one other species among his remote and now extinct ancestors, *Homo neanderthalensis*, the Cave Man. Along with the Cave Man, and other still more remote ancestors, he is also included in the next larger group, the Order of the Primates, which includes, besides men, the present-day anthropoid apes, chimpanzees, gorillas, orang-utans, and gibbons, which are arboreal and confined to the Old World, and the monkeys, tarsiers and lemurs. All these are anatomically fitted for living in trees: their limbs and digits, and in the New World monkeys their tails, are well arranged for grasping, climbing and swinging from branch to branch: the bowler at cricket, or the lacrosse player, owes much of the extraordinary freedom of movement of his upper arm to the arboreal habits of his monkey ancestors. Unlike most ground-living animals the Primates hunt by sight

instead of by smell, and they have binocular, stereoscopic vision to see their way through the trees and locate the branch to which they wish to jump. Their teeth and digestive apparatus are fitted to cope with a very mixed diet, fruit, nuts, vegetables, insects and small animals, another trait which has been of great value to man in the process of spreading all over the world into all sorts of habitats.

In turn, the Primates form but a single Order in the still larger group of the Mammals, which includes all the warm-blooded, fur-covered animals that bring forth their young alive and feed them on milk secreted by the mother—horses, deer, bears, rats and mice, rabbits, giraffes, hippopotami, whales and very many more. These animals, like the birds, which are warm-blooded like the mammals but lay eggs like the reptiles and have feathers instead of hair, keep their blood temperature almost constant and above that of their surroundings by various complicated physiological devices; in this they differ from the cold-blooded animals such as reptiles, fish and insects, whose body temperature rises and falls with that of their surroundings. In the next chapter we shall consider further how this warm-bloodedness of man affects his geographical distribution: it is a very useful asset to him in allowing him to inhabit countries with widely differing climates, so long as he can use devices such as clothing, houses, fires, air-conditioning, fans and so forth to help his automatic physiological mechanisms to keep his body temperature constant.

Then, too, the Primates, with their forward-looking eyes, and fingers and toes adapated for grasping, have considerable advantages in many ways over four-footed animals whose hands and feet are adapted only for locomotion. The horse's hoof, a single enormously overgrown finger- or toe-nail, can be used for little besides rapid progress over flattish ground or for offensive or defensive kicks: the forepaws of the mole or the ant-eater are magnificent spades or shovels but are useless for running swiftly or climbing a tree, and so on. Most mammals, in fact, are very highly adapted to certain modes of life and their

anatomy and physiology has in many mysterious ways become specialised for one kind of life, lived in one particular habitat. Man is physically very unspecialised: he still has all the bones and organs found in the nondescript early mammals that were the ancestors of the present specialised ones, and he has not, like the dog or the deer, tied the upper half of his limbs up in flaps of skin so that they can only move in one plane, nor flattened them into shovels like the mole, or into fins like the whale and seal: he has not bent his finger nails into curtain rings like the sloth nor has he, like the horse, arrived at his last toe; so that he is much freer than they are to adapt himself to living in any kind of environment, and to doing anything from digging and swimming to running or climbing in order to get his living. The absence of marked anatomical peculiarities, specialised for some particular activity, has freed him from the need to live in one particular habitat only, and his accommodating digestive apparatus has freed him from the need to live on a single kind of food; both these needs still weigh so heavily on many wild animals that if their natural habitat or food is destroyed they often disappear too.

The most obvious way in which man differs from most other mammals is that he habitually walks upright instead of upon all fours. This attitude frees his forelimbs for general use, instead of keeping them occupied with locomotion: along with these free forelimbs and his opposable thumb he has developed nerves and muscles that control the sensations and movements of his fingers and hands to an extraordinary fineness of perception and execution. But the upright stance has other drawbacks: the abdominal muscles often find it a great strain, as do those responsible for holding the back and the foot-arches up against gravity; the advertisements in magazines for laxatives, rupture appliances, corsets and foot supports tell their own tale of the price man has paid for his hands.

Man's other anatomical peculiarity, and the most important one of all, is the great size, weight, and complexity of his brain. Whereas other animal groups, in the course of evolution, took to

evolving bigger, stronger and more efficient noses, ears, limbs, tails, stomachs or what-not, man's ingenious ancestors among the Primates began to evolve bigger, better and more efficient brains, and thereby reached the top of the evolutionary tree and a position of almost unchallenged supremacy in the animal creation. I say "almost unchallenged," because it is not at all certain that man, in the process of making the world safe and comfortable for himself and his progeny, has not made it even more safe and comfortable for certain lowly groups of organisms, disease-producers, parasites, pests and vermin, and even some higher mammals such as rats and mice, and many insects such as flies, fleas and lice. But from the geographical standpoint, man's brain is of interest because by using it he can adapt himself intelligently to life in places with all sorts of varied climates, relief and other geographical conditions, and the ways in which he does this form a large part of the subject matter of our study.

There is yet another point we need to consider when thinking of man as an animal. It is quite clear, if we look at any mixed cosmopolitan crowd on a Liverpool or London pavement, that all men are not the same in general appearance. Individuals quite unlike ourselves—I am assuming for the moment that the reader is an ordinary-looking Englishman, something under six feet high, with mouse-coloured hair, fairish skin, and inconspicuous features—catch our eye at once; they have, perhaps, lank black hair, slanting eyes and flat yellow faces, or tightly-curled black woolly hair, thick lips and a dark skin; whereas most of us probably envisage ourselves privately as having the rose-petal skin, starry blue eyes and incomparable features of the film-stars on the magazine covers. These other people *look* different from ourselves. Are they in fact any different from us in less obvious ways, perhaps in psychological make-up, biological needs, or in brain power?

This is a question of immense practical importance. Visible physical differences between separate groups of mankind are a matter of simple observation, but alleged mental differences between groups physically much alike have been made the pre-

text for brutal persecution in our own day as through all recorded history. "Colour problems," based on conspicuous physical differences between groups of men, and "race problems," often based on very intangible mental, social or cultural differences, constitute some of the most intractable of all the difficulties that beset our troubled world. To arrive at some sort of answer to our question let us look first at some other animals besides men.

Wild rabbits, where they are really wild and have had no additions of blood from occasional stray tame rabbits, are so alike in looks that no ordinary person could tell one from another. They all have little white scuts and short fur of a heather-mixture brown, with a redder patch behind their ears. Tame rabbits, on the other hand, come in a bewildering variety of self-colours, patterned colours, shapes, sizes and kinds of coat, and each strain has to be kept pure by fanciers through rigorous selective breeding. A similar state of affairs is usual with most domestic animals; whereas wild dogs, horses, cattle and fowls have each a definite colour pattern to which all wild members of the species faithfully conform, their tame cousins occur in a large number of strains which differ markedly in outward appearance. When cross-breeding takes place between two distinct strains, the mongrel offspring often resembles the wild type of the species more closely than either of its parents did.

The really important point to notice here is that it is still possible to cross these strains, in spite of generations of selective breeding and extraordinary differences in appearance; they are so nearly related in hereditary make-up that parents drawn from two strains as dissimilar as the Dutch and the Angora rabbit, or the Dachshund and the Dalmatian, can still produce offspring which will be perfectly complete and efficient, biologically speaking. Now this does not occur when mating takes place outside a species. Mate a Dartmoor pony mare with an Arab stallion and their offspring will be a quite ordinary, recognisable horse; mate her with a donkey and the offspring is a mule, incapable of breeding. On this distinction is based one definition of a species; all members of a group of animals that are capable of

breeding freely among themselves and producing fertile offspring, however much they may differ in outward appearance, constitute a single species. If members of that species consistently fail to produce offspring, or produce only sterile offspring, when bred to members of another group, then these two groups are said to constitute different species. Thus the Arab and the Dartmoor, the Percheron and the Shetland pony belong to one and the same species, and despite their astonishingly different appearance are capable of interbreeding; but the donkey belongs to a separate species. This distinction between species holds for the great body of plants and animals; it fails sometimes with domestic animals and certain other groups, but it is quite a good working rule.

On this basis, all the different-looking kinds of men everywhere belong to the same species, *Homo sapiens*, because they are all capable of interbreeding and producing fertile offspring. It looks as if man, as he became civilized, has begun to vary in colour, stature and other physical features just as plants and animals do when they are domesticated. But whereas with domestic plants and animals strains are kept pure by very carefully controlled breeding, nothing of this sort has been possible with man, and his various strains, or "races," have remained distinct only where they have been sufficiently isolated geographically for mixture with other races to be very slight. Given long-continued isolation of a small group of men, inbreeding in the isolated group tends to spread hereditary characteristics fairly evenly through it, because in a few generations everyone will be a blood relation of everyone else and a general family resemblance will be seen throughout. This has happened with the Pitcairn Islanders and the natives of Tasmania, and on a little larger scale with the Eskimo, the Australian aborigines and many other island dwellers or peoples living remote from the great main body of mankind. Just as islands often have varieties, or even distinct species, of animals or plants, found nowhere else in the world—the St. Kilda wren is an example from our own islands—so they tend to have varieties of men distinct from

those found elsewhere. When first discovered by Europeans every island group of the Pacific had its own distinctive breed of inhabitants. Nowadays people get about the world so freely that geographical isolation is almost a thing of the past, and the great distinctive groups of mankind are tending to merge more and more into a common blend which, it is to be supposed, will be something nearer to plain " Man " than a Chinaman, or a Negro, or a Finn is at the present time.

Bearing in mind, then, that these different strains, or " races," of mankind remain more or less pure-bred only so long as they are prevented by geographical isolation from interbreeding with other strains, it becomes clear that in the world today such a thing as a " pure race " can scarcely be said to exist. There has been so much intermarrying among members of the white, black, red, yellow and brown groups of mankind that every possible degree of mixture of blood between, say, pure-bred negro and pure-bred European—if there was ever such a thing as a pure-bred European—may easily be found ; in fact, persons with some degree of mixture of race in their ancestry are certainly much more numerous than people of pure-bred ancestry belonging to any one group or race. Every day, as modern transport improves, the geographical barriers are being swept away that kept the different groups of mankind isolated and therefore fairly closely related in blood to others of their local group, and as the geographical barriers go so do the clear-cut physical differences between races. In some continents, such as Asia, Europe and Africa, this process has already been going on for hundreds or even thousands of years : in others, such as America and Australia, it is quite a recent phenomenon, those continents having been isolated from the main body of mankind throughout a great part of man's long history; in a few parts of the world—the fringes of the Arctic ice, and some remote islands, for instance—racial mixing is only now beginning to take place on any considerable scale. We do not know how long it takes to produce a distinct race : man is a slow breeder, and where there are many people in a group to start with it must surely take many

centuries to mix them so completely that all their descendants have a distinct physical resemblance; but we do know that the reverse process is easy, and that many distinctive groups of mankind, formerly kept racially pure by reason of their isolation, have almost or quite disappeared since they came into contact with the white man, or with the black or brown men that he has conveyed about the world in large numbers for his own purposes. Many of the isolated races died from warfare or from unaccustomed diseases against which, being isolated, they had acquired no natural resistance, but more were simply swamped by interbreeding with the new arrivals until the pure native strain disappeared. There are few Brazilians among those whose forbears have lived in Brazil for several generations who do not count at least one Indian great-grandmother in the family, though pure-bred Brazilian Indians nowadays can be found only in the most remote districts: similarly, the Carib blood survives in the yellow-skinned creoles of Martinique though there are no pure-blooded Caribs left. In Europe the various strains that have mingled through the centuries have now become so inextricably intermixed that physical appearance is seldom of much help in determining from what part of the continent a man comes, and the human population of Europe is racially about as pure-bred as the pi-dog population of India: the same holds good for a great part of the Americas and the more accessible parts of Asia and Africa.

However, since man is a slow breeder, there do still remain certain massive groups of mankind, each attached more firmly than others to a certain region, in which certain obvious physical characteristics tend to predominate, so that, to an observer strange to that part of the world, the population does at once appear to belong to a different race from himself. We can, for instance, recognise that peoples with frizzly hair, which is flattened in cross-section and curls closely over the head, peoples who also often have brown or black skins and dark eyes, occupy most of Africa south of the Sahara, as well as New Guinea and the islands of Melanesia. These peoples belong, generally speaking, to the Negroid race, and can be subdivided according to their

geographical position into the African Negroids and the Oceanic Negroids ; both of these groups are fairly numerous and occupy parts of the world which are not found very attractive by members of most other races, so that mixture of blood has gone on but slowly. Another great racial group is characterised by heavy straight black hair, round in cross-section ; the members of this group often have yellowish skins, broad heads, and flat faces with high cheekbones. These, the Mongoloids, have their main home in Eastern Asia, and have spread west across Siberia, and south-west and south into Central Asia and down into Malaya, where they have become hopelessly mixed with other races in that "second doorway of the wide world's trade." Another great group of the Mongoloids, rather darker skinned for the most part, migrated across the Bering Strait into America, probably towards the end of the Old Stone Age, and populated the Americas with all the tribes that were there when the Europeans arrived.

Between the Mongoloids and the Negroids, in a broad belt from Europe and North Africa, south-eastwards across the Near East and India and on into Australia, come the Caucasian peoples, with wavy or curly hair, oval in cross-section, eyes of all colours from blue to black, and skin, too, of all shades between very fair, in the flaxen-haired ruddy northerners round the Baltic, to brown in many of the peoples of the Tropics and sub-Tropics, and black in some aboriginal Indian tribes and in the Australian aborigines.

These three great racial groups of mankind are too widespread and too vast in numbers to intermingle completely, except along their zones of contact and in certain limited areas, such as the West Indies and southern United States, where race movements have taken place on a very big scale. But none of them is homogeneous within itself, and each of them can be subdivided further into an almost infinite number of smaller groups, less and less clearly defined as they become smaller, on a basis of stature, head-form, colouring, nose or face form, or what you will ; however, it appears from what has been said above that

unless a group of this kind is really isolated geographically and its members obliged to marry only other members of the same group, it will never develop into a " pure race," comparable biologically to a pure strain of White Leghorn hen, race-horse, or Jersey cow.

Now among domestic animals, besides obvious differences in appearance, the separate strains generally have marked differences in behaviour, temperament and physiological characteristics. Some breeds of cattle are good milkers, others good beef animals : some breeds of dog are incorrigible hunters, others prefer an easy life by the fireside : Light Sussex hens lay brown eggs, have a placid disposition, and make good mothers, whereas Leghorns lay white eggs, are nervous and flighty, and seldom go broody : and so it goes on, all through the vast number of plant and animal strains that modern scientific breeding has given us. It would be very odd indeed, therefore, if man was a complete exception, and if the varieties of mankind that differ so much in external appearance did not differ also in less obvious physiological and psychological peculiarities, just as animals do. Indeed, it is well-known to the general run of mankind that this is so : any European who has had much to do with negroes knows that in some indefinable way their minds do not work in the same way as his does, and probably the negroes notice much the same thing about him. The great Victorian scientists, such as Darwin and Wallace, keen observers, naturalists and anthropologists, making their remarkable journeys into Africa, America, Australia and all the other places that in their day were rapidly becoming more easy of access, were at once struck by the differences, not only in appearance, but in manners, customs and mentality between the Europeans that they were used to and the natives of these newly-visited countries. They noted down the existence of these differences, quite objectively, for they were good scientists, and, without going into the controversial question of whether the differences were passed on from one generation to another by physical heredity or by education, they attributed them simply to differences of " race," a word used in

those days much more loosely than it is by present-day anthropologists. But the ordinary person, who is not a trained scientist, finds it hard, if not impossible, to regard these differences objectively. All through the animal kingdom, but particularly among gregarious animals such as ourselves, the occasional oddity who differs in appearance or habits from the rest of the group is shunned, persecuted, or even driven away or killed without compunction. Men, who have consciences of many different kinds, whereas so far as we know animals have none at all, rationalise actions of this kind in an astonishing variety of ways, making themselves believe that the odd individual thus treated is a danger to the health, physical, moral or intellectual, of the whole group.

It is, alas, all too common in all walks of life, this tacit acceptance of the idea that our own relations, or the people of our own social class, or with our own particular interests, or of our own nationality, or of our own " race," are in every way better worth knowing, more industrious, cleaner, more virtuous, progressive, intelligent and well-behaved than others outside that particular group. This sort of belief is a very deep-seated human frailty, and it lies at the root of the distrust, disdain, or even hatred which so often grows up between different groups of mankind when they come into close contact, and which is so often exacerbated by pronounced differences in outward appearance between the two groups. When these differences in appearance are accompanied also by wide differences in religion, customs, or standards of living, as they generally are, the stage is set for a " race problem " or a " colour problem."

Race and colour problems are sometimes treated in modern books as if their existence were due solely to a misunderstanding of the true meaning of the word " race." The authors of these books imply that race problems have no real basis in physical racial differences : they adduce ponderous masses of evidence to prove that no pure physical race types exist, and that infinite series of gradations can be found between any two extreme types of physical peculiarity : they quote examples of intelligence tests

which reveal little or no difference in mental power between white and black, Maori and European, Indian and Jew, and they stress the point that no racial group is of necessity inferior in potentiality for great achievement to any other, given the same opportunities. They imply that if these facts were to become sufficiently widely known, race problems and colour problems would be easily solved. In my opinion this is darkening counsel: race problems and colour problems are deep emotional problems which you can no more solve by education and an appeal to reason than you can educate and reason a young man out of falling in love. They are based on the immediate, obvious physical differences in appearance and less obvious differences in mentality and habits between different human groups, differences which may produce a physical distaste every bit as real as the physical attraction between a man and a woman; they are based, too, on the deep-seated group instinct which makes us distrust or dislike those unlike ourselves, and besides these on a vast array of other psychological reactions, such as fear or jealousy, with which I am not competent to deal. A knowledge of the true nature of racial differences may help a little way towards a solution of these problems; but in the world as it is at present we have got to accept these differences between the groups of people inhabiting different areas as realities, whatever their cause, whether it be inescapable physical heredity, environment or upbringing, as we have to accept the mental reactions they produce in people who encounter members of a race different from themselves. By education we can do much to lessen the evils that result from ignorant contact between races, but colour and race problems are unlikely to be solved by education alone. Nevertheless these problems can be solved: nature has provided a way, and some nations, Brazil for instance, have taken it. The rest of the world in time will follow the same way, inevitably if more slowly, as modern transport ever more rapidly and effectively throws together into the melting pot of miscegenation the separate races of mankind, whose distinctive physical traits have for generations been preserved only through geographical isolation.

CHAPTER III

DIRECT EFFECTS OF HIS ENVIRONMENT ON MAN

SO far, in dealing with the relations between man and his physical environment we have said more about man than about the environment. We will now come to grips with the simplest of the relations between the two, direct effects of the environment on man which can be proved to result from the operation of certain definite physical and biological laws, and can therefore be predicted knowing that in almost all cases our predictions will be verified. Where inorganic things are concerned prediction is easy. We can say for certain how much a bar of iron will increase in size if we heat it up through a given number of degrees, and it will behave exactly as we have predicted. Can we predict as certainly what will happen in man if we change the conditions of the environment in which he is living, or move him from one environment to another?

The answer to this question is a qualified No. Man is a living organism, far more complex than a bar of iron, and any changes in the conditions around him produce in him a complex set of responses; moreover, no two men are exactly alike, not even two identical twins, and the same change in conditions will have a more marked effect on some people than on others. But there are certain kinds of changes in the environment, notably in the pressure and temperature of the air, that produce changes similar in kind in very nearly all individuals subjected to them, though the amount of the change may differ from one to another. As with all biological laws, the effects of any stimulus such as a rise or fall in the temperature of the air can be predicted with a fair amount of *probability* for any one individual, but never with absolute *certainty*, because there are too many variables in the complex physical body of animals such as man. Man is a parti-

cularly difficult animal to deal with because of his brain, with which he can if he chooses prevent himself from responding in the expected way to many stimuli; no thirsty dog would have behaved like Sir Philip Sidney at Zutphen. But there are certain responses to changes in outside conditions which are part of the automatic physiological activities that keep us alive, moving and breathing and eating and so on, and these responses do differ as conditions change to an extent which may alter our behaviour very considerably, whether we realise it or not. We cannot help showing these responses: by no act of will-power can we stop ourselves perspiring when hot or turning blue in the face when we begin to run short of oxygen. If they are pronounced, these automatic physiological responses to environmental conditions may have a notable effect on the distribution and activities of men.

Before going further we must be quite clear about the meaning of two terms that bear on this discussion: Response and Adaptation.

Response.

A response, in the sense that I use it here, is a biological effect resulting automatically from a particular cause or *stimulus*, such as a movement of an animal produced as a direct result of a movement of some part of its immediate surroundings. A response is automatic and quite involuntary, like blinking when anything comes near the eye, or the dilation or contraction of the iris of the eye with changes in intensity of light. Perspiring when the temperature goes up, shivering and teeth-chattering when it falls very low, are responses which we cannot prevent by an effort of will, however much they embarrass us. However, man, thanks to his brain, can also respond to physical stimuli by deliberate and reasoned actions. If we heat him up very rapidly, he involuntarily perspires, but he can also turn off the gas-fire, or take off his coat, or open a window, or eat an ice. Reasoned responses like these are unpredictable where any one individual is concerned, though I have no doubt that if you were to work out the frequency with which large numbers of people resort to the various alternatives you would find that they

did it in obedience to statistical laws of some sort. The automatic responses defined here are predictable, in kind if not in amount; they are all obvious to the eye, being the result of gross physical changes; however, it is quite possible that along with them go less obvious nervous and psychological changes which may be of just as great importance, though they have not yet been satisfactorily determined.

Adaptation.

The concept of a response is purely objective; that of an adaptation is not. An adaptation to some particular environmental condition is a modification, of structure or function or both (since it is not much use having a prehensile tail if you do not use it to swing by), that *appears to be* of benefit to the animal in its struggle for existence. There is no doubt, for instance, that if an animal wants to live on land, lungs are an advantage for doing so: the drawbacks of sticking to gills are forcibly presented in Mr. Hatch's story of the Curious Lobster who went exploring on land and was perpetually trying to avoid drying up. Wings of some sort, whether of feathers, or of skin, or of wood and aluminium, are useful to an animal taking to the air. But where other "adaptations" are concerned, it is often more a case of what we think they ought to be good for, than what use is actually made of them: what real use is its desert-coloured "protective" plumage to a Saharan hawk, who has no enemies from which to be protected? We have no idea of the answer to this question: geographical determinism is as good a one as any other. For convenience we still speak of "protective" colouring as an "adaptation" to life in certain conditions, and there is no doubt that to many animals, such as ground-nesting birds, it must be of real value in the struggle to live and rear offspring.

Then there are certain phenomena which fall into a kind of borderline class between responses and adaptations—perspiration for instance. It is an automatic response to rise of temperature, but it is also an adaptation to life as a warm-blooded animal of constant temperature on a globe where the air temperature fluc-

tuates much and often. Many responses like this appear to have a protective value, but if they are automatic and clearly related to specific stimuli they are still responses whose immediate causes we know, not adaptations about whose causes we are still ignorant. Perspiration, on this basis, is a response to the stimulus of heat: the woolly hair, like that of an Airedale dog, of many tropical pigs, is an adaptation to the intensity of tropical sunlight, since it *appears* to save the pig from sunstroke, though we have no idea whether the hair is at the same time a response to the light.

The direct responses called out in man by changes in his surroundings are mainly the result of changes in climatic elements such as the pressure and temperature of the air, which is the most changeable part of our environment. These changes affect us directly, through the skin; we feel them at once when they happen, whereas changes in the soil, or the scenery, or the life surrounding us affect us only indirectly through our food or our sense of sight or through still more subtle psychological channels. We will now look first at man's direct and obvious physical responses to changes in weather and climate.

Pressure.

The barometric pressure at sea-level is constantly changing, but only through a comparatively small range, at most from about twenty-eight inches of mercury at the centre of a tropical hurricane to about thirty-one inches at the centre of a very intense anticyclone. Changes of this amount have not so far been proved to have any direct physiological effect on us, though Ellsworth Huntington, the founder of the so-called "Cambridge School" of Geographers in the United States, maintains that the storminess consequent on a rapid succession of such changes is a great stimulus to mental and physical activity, and a principal cause of the supremacy in our present mechanised civilisation of the peoples of the North Temperate zone.

To produce any measurable physiological response changes in pressure must be greater than this, of the size one meets in going up to higher levels in the atmosphere. Mountain sickness, the

"soroche" of the Andes, an unpleasant combination of splitting headaches, nausea, and, in bad cases, of bleeding from the nose and ears, affects people going up into high mountains, though the level at which it first occurs varies very much with the individual: some people begin to feel it after ascending only a few thousand feet, others not until they reach twelve or even fifteen thousand feet. But when living at these levels the worst effects generally soon pass off in healthy people, and in a few days they become partially acclimatised. At greater heights, however, acclimatisation gets more and more difficult, and at about twenty-five thousand feet there appears to be a critical zone where everything seems to change for the worse and the odds are all against even the best-trained mountaineer.

The cause of these effects is the diminution of the pressure of the air with ascent. At ten thousand feet the pressure is only seven-tenths of the sea-level pressure; at seventeen or eighteen thousand feet it is only half.

But it is not the fall in the total pressure that causes the trouble, but the fall in the partial pressures of oxygen and carbon dioxide with consequent effects on the process of respiration. The gas pressure of the blood in the lungs is beautifully adjusted to an exchange of gases between the blood and the air at sea-level pressure. But if the pressure of the gases in the surrounding air falls, as it does at high altitudes, this balance is upset, and the blood, and hence the body, begins to run short both of oxygen and of carbon dioxide. This shortage first produces symptoms such as a tendency to puff and blow on taking exercise, and a bluish colour of the fingernails. These symptoms may be seen in some habitual lowlanders at heights as low as two or three thousand feet, but the next and worse symptoms, headache and sickness, seldom occur below eight or nine thousand feet. In a very short time, often only a few hours at these levels, the symptoms diminish, because the body is responding to the diminution of pressure by such means as pouring out more red blood corpuscles into the blood-stream, a process which helps to relieve the oxygen shortage by increasing the available transport.

After a week at a level of ten thousand feet or so most people scarcely notice any unpleasant effects of the altitude unless they take strenuous exercise; they often, however, feel exhilarated; possibly an abstemious use of oxygen has something of the same effect as an abstemious use of food appears to have in religious ascetics. It is commonly found, however, that living a long time at these altitudes has a depressing effect, and those not born and bred there find that they need to take frequent holidays at lower levels to get over the nervous irritability often produced by living continuously at these heights. Very high altitudes definitely affect mental capacity adversely: calculations simple to do at sea-level are frequently done wrong at high altitudes, judgment and initiative are lost, and any prolonged mental work produces far more exhaustion than it does at low levels.

Panting, blueness of the face and nails, and mountain sickness are responses, unpleasant but immediate, to the fall in gas pressures as we go up a mountain. After a short time we become acclimatised; the body develops temporary physical adaptations which reduce the impact of the adverse conditions on the body, even in people who have not been living long at high levels. Natives of these high places have a number of permanent physical adaptations to their rarefied air, some obviously and others not so obviously useful. They are often extremely able and highly muscular; Peruvian Indians can do as much hard work in the mines at altitudes of over seventeen thousand feet as an English labourer can do at sea-level. Mountain dwellers breathe more slowly, but more deeply, than lowlanders: chest expansion in young Peruvian highlanders is said to average 3·5 inches, in adults 3·2 inches, as against 2·9 inches for tall and physically well-developed North American students. Their legs are longer in proportion to their bodies, as measured by the relation of seated height to total height, which in Davos highlanders is 43½ to 45½ per cent, while in lowlanders of similar physical type it is 53 per cent. There are various other adaptations which appear to give an increased intake of air, such as a bigger chest circumference in relation to body size, and a widening of the

angle between the ribs and the breast-bone. It is interesting to find, however, from the records of many travellers, that natives of high altitudes such as the Sherpa porters in Himalayan expeditions, when taken to still higher ones, often suffer more from mountain sickness than the Europeans who are not permanently adapted to life at high altitudes but have only recently become acclimatised to it. The rule that the more specialised an animal becomes the closer it is tied to its appropriate environment seems to apply even in this apparently mild example of specialisation for a particular environment.

Mountain sickness, and the great difficulty experienced in doing even very simple things at very high altitudes, is obviously a deterrent to permanent settlement. In both the Americas and in Central Asia the upper limit of settlement—not necessarily even permanent settlement, as much of it is during the summer only—is at about 16 to 17,000 feet. Here the pressure is slightly more than half that at sea-level, and the mean annual temperature is round about freezing point. But the upper limit of settlement is more often defined by the position of the snow-line than by difficulty in breathing: on the great dry plateaus of Tibet and Bolivia there is a fairly dense population living at between 11,000 and 12,000 feet, whereas at these altitudes the Alps, the Southern Andes and the Canadian Rockies are a wilderness of ice and snow. La Paz, the most astonishing of high-altitude cities, has a population of 150,000 living at about 12,000 feet, though this figure means little as there is about 3,000 feet of difference between the highest part of the city and its lowest suburbs, and people who suffer from insomnia as a result of the altitude in the higher parts can often sleep in the lower ones. Lhasa, with about 20,000 permanent inhabitants, lies on a flat plain at 11,800 feet, and Shigatzé, with 14,000 people, at about 12,000 feet. Many mining settlements in the Andes are higher than this: the workmen at the sulphur mine of Aucanquilcha in Chile, itself at 18,800 feet, live at 17,500 feet and begin their day's work by walking up 1,300 feet through sand and powdered sulphur; when in the mine they can do as much work as the ordinary man

can do at sea-level, and after a hard day's work will spend an evening at 17,500 feet practising football. However, Tiahuanaco, the ruined city of the great pre-Inca civilisation of the Andes, lies now at 12,600 feet, higher than La Paz, though there is reason to suspect that the Andes, which are still rising, may have been at least a little lower when it flourished. Cuzco, the Inca capital, stands at 11,400 feet, Mexico City at 7,500. Against these, the high cities of the Rockies and the East African plateau seem almost in the lowlands, though Addis Abbaba stands at 8,000 feet: Denver, Colorado, is only 5,270 feet, Nairobi 5,450.

Other climatic elements: Temperature, Humidity, Radiation from the Sun.

It is easiest to take the effects of all these elements together, because the responses that they produce in man are all connected with the fact that he is a warm-blooded animal like the other furry mammals, albeit an oddly hairless one. Cold-blooded animals like the fish and the frog take up roughly the temperature of their surroundings: fish can live for quite long periods frozen into blocks of ice, while the goldfish kept in a pool in the Crystal Palace survived the great fire that burnt it down, during which their water must have narrowly missed boiling; this distressing experience turned them permanently black. Very high temperatures kill animals by coagulating the proteins in their protoplasm, a process similar to the setting of white of egg when boiled; this fact is made use of in sterilising soil, infected clothing and so on. Some bacteria, however, notably the ones responsible for food poisoning, will survive even long exposure to temperatures above boiling point. The activity of cold-blooded animals is affected by changes of temperature; they move about more quickly and their life-processes go on faster at higher temperatures. On a suddenly chilly evening you can pick up outside a hive many seemingly dead bees, too cold to move at all; warm them in the hand or by a fire and they begin to move, and a few minutes later if kept warm they are ready to fly. Shapley found it possible to tell the air temperature correctly to within one degree C. by a single observation of the speed of

trail-running ants, which ran ever more rapidly as the temperature rose.

Warm-blooded animals like birds and rabbits and men have a body temperature which remains almost constant at a level a good deal higher than that of the air about them, and it varies little in health, though it may rise for a short time during and after violent exercise, and in hibernating animals like dormice it often falls very low, almost to that of the outside air. Our normal temperature is 98·4° F. and we feel extremely uncomfortable if it rises to 101° or 102°, though much of this discomfort may be due to the toxins of the disease we are suffering from; birds, on the other hand, often have very high temperatures, that of the pheasant being 108·5° and of the swift 111·2° F. This is the temperature of the important internal organs, in particular the brain; the skin, which is charged with the responsibility for keeping the temperature constant by getting rid of excess body-heat, often varies through a much greater range of temperature. The heat of the body comes from internal combustion of food, as we saw in the last chapter; we will deal with this effect of food more fully in Chapter VI.

In man the skin controls loss of heat in two ways: firstly, by changing its own temperature and so the rate at which it loses heat directly to the surrounding air; this is done by mechanisms controlling the supply of warm blood to the skin: secondly, by evaporation of water from the skin's surface, in the form of invisible or visible perspiration. Cooling the skin by the first method is similar to cooling a hot teapot in the air; it can be retarded by a suitably cosy cover in both cases. The second kind of cooling is the same as that we feel when sitting in wet clothes, or the cold the Boy Scout feels when he holds up a wet finger to test the wind.

Thus when the air temperature rises our skin flushes warm and so loses heat more readily; it warms up because the little arterioles that bring blood to the skin increase in diameter, so that more blood gets through and can be cooled close below the surface. At the same time the sweat glands become more active,

and so more heat is lost by evaporation. When the air temperature falls the arterioles contract and less blood gets to the skin, which turns first pale and then blue and feels coid; the sweat glands stop working, though water continues to be lost in small quantities by some other means, probably by actual diffusion through the skin itself, as Polar explorers have noted to their cost. Careful measurements show that the amount of water ordinarily lost from the skin without visible perspiration is a little over two pints in twenty-four hours.

These responses to a fall in temperature—cooling of the skin and slackening of perspiration—are merely defensive measures; when we get really cold active measures become necessary, and we start to shiver and our teeth chatter, as a hint to us from the automatic part of our bodies that some exercise might warm us up a bit. If cooling continues beyond this point, according to Barcroft, the body seems to give the effort up in despair; the limbs relax, the skin glows, and a delicious sensation as of basking in warmth is felt, after which it would seem probable that sleep, and then death from cold, follow in rapid succession; however, the earlier effect appears to be deliberately produced by certain Tibetan mystics, who in this condition can sit naked in the snow all night, or dry on their bare backs sheets saturated in water from an ice-covered lake.

So far we have considered only the effects of alterations of temperature, but humidity is concerned also. The amount of cooling that can result from the evaporation of perspiration depends partly upon the amount of water that the air can take up, or its Relative Humidity (see volume in this Series on Physical Geography). Cold air can take up very little moisture in any conditions, as we know when we try to dry clothes out of doors on a cold day, and so in cold weather the heat loss from the skin has to be managed almost entirely without the aid of evaporation. Hence if we heat ourselves up by skating or other strenuous exercise in cold weather our skins begin to glow, and we lose our extra heat by radiating it out to the air like an electric fire. On the other hand hot dry air can take up a lot of

water vapour, and on hot summer days our perspiration often disappears into the air as fast as it is formed, leaving only a layer of salts behind on the skin: men doing strenuous work in deserts may evaporate more than 2½ pints of water per hour from the skin, and may suffer from heat cramps owing to the loss of all the salt needed for this enormous quantity of sweat, unless they take in replacements by drinking slightly salted water. However as they get acclimatised to these conditions they produce less concentrated sweat and more of it, so that they are kept cooler but economise on salt.

In hot air with a very high Relative Humidity, steamy suffocating air like that in the Tropical House at Kew, loss of heat by perspiration is not easy, as the air is already nearly saturated with moisture and cannot take up much more, while the high temperature makes us perspire readily. Perspiration pours off our faces and saturates our clothes if we do hard bodily work in such conditions, and we feel great discomfort at lower air temperatures than we can stand easily in dry air. Thus the effect of air temperatures on our bodies varies with the degree of dryness of the air, because our body temperature is partly kept constant by evaporation of sweat, and the rate of evaporation of sweat is controlled by the humidity as well as the temperature of the air around us.

When the surrounding air gets to a temperature higher than about 95° F., it may actually warm our skins instead of cooling them, unless this warming effect is offset by cooling by evaporation. At this point heat-stroke from excessive rise of body temperature is likely; the temperature at which it may occur ranges from about 106° F. if the air is half-saturated to 95° F. if it is very moist. But even at ten degrees lower than these temperatures conditions are already becoming very oppressive. Research being carried out at the Psychological Laboratory in Cambridge shows that when the temperature gets above this lower point all kinds of work, whether physical or mental, are less efficiently performed; sleep is more broken, and attention wanders even though the subject is trying his hardest to con-

centrate. Such temperatures are not very common in the open air, though they are found in, say, an airless jungle clearing when the sun shines after rain. In climates that approach these conditions, such as one finds in Malaya, the Guinea Coast of Africa, British Guiana and the valley of the Amazon, activity is clearly affected; the body has to be driven to perform active work, which is physiologically bad for it unless its heat-regulating mechanisms are in very good order, because activity much increases the amount of heat that has to be lost. This tends to raise the temperature of the blood supply to the brain, which thereby functions less efficiently, and it puts a heavy strain on the heart, which has to pump more blood to the skin in the effort to cool the blood faster. Irritability, a first symptom of the loss of the very highest controlling faculties of the brain, is common in white men who have lived long in the humid tropics. The value of air-conditioning in such circumstances seems to be that it reduces this mental and physical exhaustion. Sleep in an air-conditioned room is sounder, longer and more refreshing; work in an air-conditioned room is better and less tiring, and more is got through in a day.

So far we have not mentioned radiation from the sun, which further complicates the picture which we have drawn of the physiological relations between man and his environment.

All men except albinos possess some skin pigment, a substance known as *melanin*, which can absorb all the rays of sunlight except those at the red end of the spectrum. We cannot long bear the heat of the rays of the sun concentrated on to the skin by a burning glass, but if we place on the hand a drop of a suspension of melanin in water and concentrate the rays through that, we feel no discomfort, as the melanin has absorbed the rays before they reach our skin. This pigment, then, acts as a protective screen against the damaging action of the sun's rays of shorter wavelength, which as we know can cause reddening and blistering if we rashly expose our bare limbs to the sun at the seaside or in the mountains before we have become acclimatised by developing more pigment. In time the melanin

in our skin increases in response to the radiation; we tan, and cease to get sunburnt after exposures which would have blistered us badly before the extra pigment was formed. But a darker skin absorbs heat from the sun more readily than a lighter skin, and so we do in fact get hotter lying in the sun after we are well tanned than before. A negro's dark skin absorbs direct heat in this way more easily even than ours, and so he is really at a disadvantage in direct sunlight, though by reason of his dark colour he can also lose heat by radiation from the parts of his body in the shade more readily than we can with our paler skins. He is entirely protected against casual sunburn by his screen of melanin.

The slightly-delayed response of the body to light is, then, an increase in pigmentation of the skin, but is a permanently pigmented skin really a valuable adaptation to life in the Tropics? This is one of the most debated questions in human geography. Much of the trouble lies in the fact that skin colour is hereditary: the children of black parents are black, whether exposed to the sun or not, while the children of fair parents would be born fair, even though both parents were nudists and had tanned all over to the colour of a Red Indian. The black pigment of the negro does seem, however, to differ in some ways from that of the Australian blackfellow: Max Sorre makes the somewhat macabre observation that the corpses of negroes have black pigment scattered irregularly throughout their tissues, even in the grey matter of the brain, whereas those of Australian blackfellows have no black pigment internally and bleach on exposure to the sun. As we have seen, the coloured man is at a disadvantage compared to the white man in direct sunlight, but as a result he sweats more; often, too, he has many more sweat glands per square inch of skin, and this helps to keep him cooler, and he also loses more heat by direct radiation in the shade. He is much better protected against the bad effects of too much ultra-violet radiation. On the total, is his dark skin really more useful to him than a white one when living in the Tropics? Probably yes: the Poor Whites in the West Indies, working as labourers

in the cane-fields, suffer fearfully from sunburn, and their general low level of intelligence and industry, though it has many other social and physiological causes as well, may be in part due to the effects of physical conditions to which they are unable to adapt themselves satisfactorily.

Wind.

Wind is a feature of climate that undoubtedly has many direct effects upon our bodies and possibly even more upon our minds, but so far no-one has contrived to measure these effects satisfactorily. A wind, so far as it affects animals, has properties distinct from those of the air of which it is composed. It may be physiologically drier than that air, because it continually removes the layer of saturated air which in the absence of the wind would form close to the skin and slow down evaporation. For the same reason it may be physiologically colder than still air at the same temperature and humidity, as we all know well from experience. It impedes movement, and may exasperate us by the way that it makes simple things more difficult to do, as anyone who has tried to write surrounded by loose papers, or cut out material for a dress, on an island under the Trades, will know very well; you cannot shut all the windows, because the hot moist air in the house soon becomes intolerable unless it is moving, but if you open the window everything blows off the table.

Cold winds, hot winds, dry winds, dusty winds, they all affect us strongly, but in different ways. Winds peculiar to certain districts, alone among the features of the climate, are given personal names in every language and every place; the winds are personified as good or bad spirits, gods or devils, by simple men everywhere. In a thousand direct and indirect ways the winds affect our lives, causing thousands of pounds' worth of damage yearly in places like the United States subject to violent gales, controlling heat and cold, rain or drought, and even, it appears, the state of our health at times, but no-one has yet provided any scientific evidence for direct physiological responses to wind similar to those found for responses to changes of pressure

and temperature. There is a vast field of research here waiting to be tilled by the physiologist, the psychologist and the bio-geographer. The same may be said of atmospheric electricity, of whose effects on man even less is known definitely than of the effects of wind, though many of us are well aware, just before a thunderstorm, of a strong feeling of discomfort which may well be due to electrical changes in the atmosphere.

Solid matter in the atmosphere—fog, dust, pollen grains and so on—also affects us in a great variety of ways; many newspapers in the Middle West of America publish the day's pollen count on the front page for the benefit of sufferers from hay fever, while fog, by restricting visibility, is even more troublesome than pollen, and causes an immense total of economic loss by slowing down transport, and even on occasion loss of life. Not all of these, of course, are plain physiological effects, but there is no doubt that the solid matter in the atmosphere forms a very important item in our physical environment as a whole.

We have so far considered only direct responses to changes in our surroundings, but since we are reasoning beings these direct responses are generally helped out by reasoned ones directed to the same end, that of keeping our brain and internal organs in the right condition to function properly. The brain, through the possession and use of which we can adapt ourselves to life in almost any extreme of climate met with on the earth's surface, in order to function at its best must have a supply of blood as nearly as possible constant in physical and chemical properties. If a change in outside conditions is too great for the body to cope with by means of its usual responses and adaptations, the first sufferer is the brain, and its failure to act properly is shown in various ways: apathy and lack of initiative when short of oxygen is as much a result of the partial breakdown of the highest functions of the brain as is increasing irritability when the air gets too hot for our usual cooling mechanisms to keep our temperature down. It is always the highest functions of the brain that are affected first. But at this point man is often able to help out his body by taking intelligent

steps to improve the physical conditions that are causing the trouble. The study of these reasoned adaptations to physical conditions makes up a large proportion of the literature on human geography, so that I shall not do more than mention a few points here.

Clothing and shelter are obvious ways in which man can adapt himself to uncomfortable climates. Lefevre has estimated that 77° F. is about the critical temperature at which the body's heat-regulating mechanisms go into reverse and change over from losing heat to conserving it, or vice-versa. Below this temperature clothes are helpful in conserving heat: above it their use varies. If the air is intensely hot, as it is in the Sahara in summer, they may help to keep the body cool; the loose flowing robes of the Tuareg keep a comparatively cool layer of air next his body, protect him from the direct rays of the sun which would make him hotter still, prevent him from losing moisture from the skin which he can ill spare, and protect him from dust. But an Indian of the Amazon, with the temperature at 82° or 83° and the air saturated, finds it better to go without clothes because they impede evaporation, which is the only way by which he can keep his temperature down in these conditions; direct sunlight worries him little, under the dense shade of the great forests, and of course there is no dust, though clothes might be useful as a protection from insects. The Arabs of the towns live in thick-walled houses with small windows to keep out the glare and the parching wind; the Amazon Indian protects himself from the rain only, living under a roof supported on poles, open on all sides to the longed-for breeze. Contrasted with these two, the Eskimo shelters in winter in an igloo built of porous blocks of snow and well insulated against the cold; when outside he wears thick fur clothing that covers him completely, to retain all that he possibly can of the body's heat. But it must be pointed out that adaptations like these, which seem so sensible to us, are by no means universal. The blacks of the Australian Aboriginal Reserves go stark naked in a climate like that of the Sahara, with summer day temperatures up to 120° F.

and little shade, with pests of ants and flies worse than the Saharan dust-storms and more continuous. The people of Tierra del Fuego go as naked as the Australians in a climate less attractive even than that of the lands of the Eskimo, with summer temperatures scarcely higher than we get in the south of England in March, winter temperatures little above freezing, and almost continuous cloud, gales and cold sleety rain. Neither of these peoples constructs any permanent dwelling. Clearly in studying the ways that man reacts to climate many more factors have to be taken into account than purely physiological ones, things such as the stage reached in material culture, tradition, mode of life, contacts with other peoples at a different stage of development, and so on.

To end with, I think we can summarise our study of man's reactions to changes in his physical environment, in the last two chapters, as follows : Man is an animal that can live in a greater variety of physical conditions than any other animal, by virtue partly of his unspecialised body and partly of his excellent brain, which devises means to make the most unpromising surroundings reasonably comfortable. For his brain to do its best work its internal environment, physical and chemical, must be kept stable. When outside conditions become so extreme that this internal stability is threatened, all sorts of protective physiological responses are called into play, and if conditions remain extreme the body adapts itself by means of more permanent alterations in its structure and functions. This most useful power of adaptation, if kept too long on the stretch, loses some of its elasticity, and people acclimatised to life in one uniform set of conditions are not so happy in different ones ; perhaps by this fact we may in part account for the way in which Europeans, used to the very changeable climates of Europe, have spread all over the globe and adapted themselves to every other kind of climate. But also, man can devise ways of improving his living conditions if he does not like the climate—clothing, fires, electric fans, air conditioning, refrigerators, and innumerable other devices are the result of his never-ending battle against physical

discomfort. He builds up artificial " micro-climates " inside his houses, and when he has to take an unpleasant local climate as he finds it he can adopt the measures already found effective by people born and bred in that climate, in order to live comfortably. In all these ways we see how climate affects man, and how carefully the geographer must take it into account in judging whether any group of men have really succeeded or not in living well in a given environment, to the benefit of their own health and happiness.

Before passing on to the next chapter I would like to stress again what I said at the beginning of this chapter; the direct physiological effects of the environment which we have been discussing here are *inevitable*. If men are going to live in extreme conditions and produce their best physical or mental work, they must begin by deliberately taking into account their physiological limitations, and adapting their own clothing, houses and way of life to the local conditions. This is one of the first and most elementary principles of Human Geography. It applies equally well, of course, in our own country, where conditions are less extreme but more variable. Perhaps it seems to you too obvious to be worth saying at such length as I have done in this chapter, but if you are to learn to be a Biogeographer the first thing you need to acquire is the right point of view. So next time you find yourself throwing open all the windows on a still, stifling summer's day and then complaining of the heat, think of the Arab in his thick-walled dwelling shutting *out* the hot air, and ask yourself whether you are really making the best possible adjustment to your environment. Notice in yourself what happens to your heat-regulating mechanism when the air temperature passes the critical point of 77° F., how your mind works when the wind changes, or when you are feeling too hot or too cold, and so on. Once you begin to think about the environment in all the ordinary activities of everyday life, and your own and other peoples' reactions to it, you will be beginning to develop the viewpoint necessary if you are to become a sound, practical Biogeographer.

CHAPTER IV

MAN, ROCKS, AND WATER

YOU do not need to be a geographer to notice changes in the weather; they are only too familiar to all of us. But possibly you are not so used to noticing the rocks below your feet and thinking of them as part of your surroundings, unless you happen to live in striking scenery with crags or sea-cliffs or quarries that call vividly to mind your local granite or chalk or slate. To the geologist and the geographer "rock" is a general term for all the solid material of the crust of the earth, whether hard gneiss, granite or limestone, softer sandstone, chalk or shale, or even quite unconsolidated material like gravel or clay or wind-blown sand. Most of the loose deposits were laid down very much more recently than the compacter rocks underneath them, perhaps only in the last few centuries, by winds or rivers; or they may be slightly older, laid down by the glaciers that covered most of this country during the Great Ice Age. On geological maps the underlying older, harder rocks are classed together as comprising the "solid geology" of the district, the upper, looser sediments being called "drift." But as far as the part they play in our lives is concerned their age does not matter much; what does matter is the kind of material they are made up of, or their *composition*; the way they are arranged, or their *structure*; and the landforms and scenery, or *relief*, that they give rise to. There is also a close correspondence in this country between the rock below and the soil above it, but soil is such an amazingly complex affair, and its properties depend so much on many other things besides the parent rock—climate, vegetation, and the creatures living in it, for example—that we shall leave it out of account for the moment. Here we will deal first with the effects on man of rocks alone, their composition, structure, and the relief that they give rise to.

When you travel by road or rail, do you think about the scenery as you pass it? If you really look at it and think about it, you cannot fail to discover how much our English landscape owes to the great variety of our surface rocks. Here, let us say on the outskirts of London, up the Thames valley, it is all market-gardens and allotments, fruit orchards and small suburban houses; a road cutting runs through sand or gravel, easy to till and good as a site for dry comfortable houses. There say in the low-lying parts of the Weald or Northamptonshire, you see green meadows and cattle grazing in them; each meadow has its pond, and tall shade trees; farms are scattered and hidden and there are few cultivated fields. By a hole dug in the road are lying heavy lumps of stiff clay; but indeed it was clear already from the change in the landscape that the soil must be clayey—how could so many ponds survive on gravel?—and surely the tall chimneys on the horizon belong to brick kilns? Again, in the Pennines or North Wales, you come to bare uplands with stone-walled fields and wastes of heathery moors; the farms are solid and squat, stone-built and roofed with stone slabs, split slate grey as the grey stony landscape. Every different rock of our ancient and varied homeland gives rise to different scenery, with different soil, different buildings and different farming: each has its own peculiar and distinctive landscape, which should at once strike the geographer's eye as related to the underlying rock.

We are fortunate in Great Britain in having so large a variety of rocks in so small a space. Whenever you travel, the view changes often and often; try to observe the changes and account for them; look for gravel pits, quarries, road and railway cuttings and excavations of all sorts. Look at the soil in new-ploughed fields, rich brown on the clays, anaemic on the chalk, mahogany-red on the red sandstones of the west; look at the materials used to build the older houses, the churches and walls; you will soon learn to read more meaning into many of the changes of scenery when you find that you can explain them, at least in part, by the steady long-continued influence on man of

the rock on which he lives. At the same time you will begin to acquire the geographer's "eye for country," which will give you as much pleasure on an ordinary rail or bus journey as an "ear for music" will give you at a concert.

When a Cotswold farmer builds his new barn with the stone he has dug from his own quarry, or the West African negro forges a hoe-blade from iron he has himself smelted from local ore, we see the influence of rock composition on man in its most direct and simple form. Each kind of rock has its own peculiar uses as a raw material, whether for building or for industry. Each of them has different and specific techniques which man must master before he can use the rock to best advantage, splitting slate, knapping flint, making glass from sand, or bricks and pottery from clay. By the process of finding out the right techniques and using them man deliberately adapts himself to his natural surroundings in one of the most direct ways.

This direct influence of the local rock on man plays no very great part in the lives of most of us, and it is shrinking steadily nowadays as we take to relying less and less on the natural materials that we can find close to hand. But it is still seen very clearly in mining areas, where everyone is concerned directly or indirectly in working the local rock; obviously, too, if the coal or the salt were not there below the surface, towns such as Barnsley or Whitchurch would not be there above it. Rocks, in fact, are quite simply the parents alike of the Rand and the Ruhr, of the oil cities of watery Maracaibo or the parched nitrate camps of the Chilean desert. Here population is directly controlled, in its amount, its distribution and its activities, by the composition of the local rock alone.

The same influence shows, but less overwhelmingly, in the ways in which local rock has been used for building. The craftsmen that built our older towns and villages took to using the stone or clay they found to hand; as they learnt ways to master their material it in turn moulded them, and their technique and style gradually became adapted more and more completely and beautifully to their material. They used the rock lovingly,

treated it respectfully as the craftsman must, with due regard for its behaviour and appearance, and did not distort it into inappropriate forms, so that the houses, walls and churches that they built weather into the landscape as easily as the rock itself from which they came. They are as perfectly fitted to it as the nest of the goldfinch to its apple-bough, the one made from the very cobwebs and grey lichen that clothe the other. Modern Local Authorities, using imported pink brick and mauve slates for their housing schemes in a country of creamy limestone or fox-red sand, may indeed have tried to adapt their schemes to the economic and social environment, but they have lamentably failed to adapt them to the physical one. However cheap and convenient such houses may be, they are not a good and complete adaptation to the whole environment, because they look ugly and inharmonious in the natural landscape.

Besides the buildings, there are other parts of the man-made landscape that depend directly upon the local rocks. In the North and West of England many of the rocks are hard and weather slowly; the soil is thin and stony, difficult to work or to convert into good pasture. There is too much rock; all through the centuries farmers have been removing rocks from their fields and pastures to get them out of the way, and have built them up into walls round the fields to keep their beasts from straying. The walls are as clearly controlled by the rocks as are the houses. In Cornwall, in the slate country near Fowey, they are made of small neat flakes, set on end in groups or lying this way and that in checker-board or diamond patterns; the walls are double and the middle is filled up with earth on which grow foxgloves and furze, to give a substantial and very beautiful wall made of innumerable small flakes of rock. In Wales, in the Snowdon district, big irregular lumps of the local gneiss are built with amazing patience and precision into enormous mortarless walls, sometimes six or seven feet high so that even sheep cannot cross them, running along and up and down the mountains, fitting themselves to every curve of the rough ground and every outcrop of the natural rock. In the extreme North of

Scotland by John o' Groats great flat slabs of the local black rock set on end side by side, form the economical and uncompromising hedgerows of that desolate land. And where there is no waste rock to make walls, our forbears planted hedges instead, or in the last resort, in the rich but over-watered Fens, they dug ditches, which served like the stone walls of the North to get rid of an over-abundant commodity as well as delimiting the fields. Perhaps the hedges and ditches are not so clearly related to the local rock as are the walls, but look at them more closely: you will find hawthorn, elm and crab-apples on the heavy clays and loams, beech on the chalk, pine or lilac on the barren sands of the East Anglian Breck, and heaped-up banks of earth knitted together with furze and bracken on the light soils overlying sand and gravel. Everywhere you go, you will see in our age-old landscape the results of the slow untiring influence of the local rocks, working throughout the centuries on the men that live upon them.

In other countries the close relations between rocks and man often appear very clearly. In the Upper Amazon valley, the Great Plain of China, or the Argentine Pampas, plains made of fine silty sea and river deposits without a pebble as big as a walnut for hundreds of miles, the lack of hard rock has often been a real handicap in settling the country. Prehistoric men living in these places had to rely mainly on wooden weapons, and trade for their rare stone axes with tribes hundreds of miles away. Later settlers, more advanced, have had to evolve ways of building houses of sods or of pounded earth—until they could import corrugated iron and wood cheaply, if the plains were treeless—and the lack of good road metal or railway ballast to hand makes transport even nowadays costly and difficult. It may be due in part to this lack of rock that the Argentine has relied for so long on sheep and cattle rather than on crops; animals can walk to the ports and packing stations, even if the roads are smothered in dust in dry weather and sloughs of mud after rain; wheat and maize must be taken by train.

At the other end of the scale, man's earliest shelter so far as

we know was a natural rock cave, and the grottoes, rock shelters and caverns of France and the Pyrenees, in which magnificent drawings and sculptures of the Old Stone Age have been discovered, give us a glimpse of the part rock played in the life of very early man. He made his tools and weapons of stone, generally flint mined from the chalk, and where the local rock was not suitable traded for better kinds ; the superb brown flint used by the Solutreans of Central Europe was brought from the South of France, and special rocks such as the black obsidian of Melos in the Aegean Sea were traded far from their place of origin, as in prehistoric America were the obsidian of the Yellowstone region, or the red pipe-stone used for making peace-pipes, found only in Dakota but traded all over North America. More remarkable still were the distances early man brought enormous monoliths for his sacred buildings ; those of Stonehenge came from Pembrokeshire, and were probably brought by water to very near the site, but we have no idea how the ancient Peruvians moved the colossal " Tired Stone " outside Cuzco, a monolith of rock unlike any outcrop nearer than Quito, nearly 900 miles away over appallingly difficult country. Early man, like ourselves, did not necessarily always use the material that lay nearest to hand. The finest Inca and Pre-Inca buildings in Cuzco are made of great blocks of green stone brought many miles to the city ; the Spaniards used the pink rock found on the spot, and the contrast between the old work and the new strikes the eye at once. Whenever man wishes to show particular reverence to his gods or to make a parade of his own wealth and importance, he uses rock, the rarest, most beautiful and most enduring stone that he can get ; Westminster Abbey was built of Portland stone, not bricks baked from the London Clay ; banks, insurance offices and Lyons' tea-shops flaunt the wealth that built them in slabs of exotic porphyries and ornamental marble.

The ordinary man, however, lives in an ordinary house which used to be built of local materials, whatever was nearest and most abundant. Unfortunately, in these days of high wages and cheap transport it is usually cheaper to use machine-made, mass-

produced bricks from a distance than bricks made by hand from the local clay, or hand-worked local stone, with great loss in beauty as a result.

Rock, then, has many direct uses as a raw material. Building stones, roofing slates, paving slabs; gravel for paths; granite for road-making; clay for bricks or pottery or china; sand for glass; limestone, chalk and marl for cement and a host of other uses in industry; special stones for grindstones, tombstones, marble tops for expensive furniture, fishmongers' slabs, ornamental pillars for busts—there is no end to the uses of rock as a raw material, even leaving out of account the highly specialised rocks such as coal and the mineral ores. With your improving geographer's eye, look now for examples of stone used as a raw material; see if the result is well adapted to its purpose and satisfying to the eye, a good use made of the natural resources of the environment. Look for the local influences in the buildings of your town or village; learn to note when you travel the subtle changes that show when you have moved off rock of one kind on to another; observe the scenery and the differences in the use of local resources that helps to produce the spirit of a place. And then, to put your growing geographical knowledge into use, try to decide whether you could have done better than the local people have done in fitting yourself, your buildings, roads, walls and towns unobtrusively and attractively into the landscape, whether you could, in short, have adapted yourself better than they have done to their physical environment.

Rock Structure and Relief of the Ground.

Whatever the surface rock may be, the form of the landscape that results is due not only to the rock but to the action upon it of all sorts of physical, chemical and organic agents, which in most places combine to cover the landscape with a layer of soil and to carve it into a great variety of landforms. These landforms owe their characteristics both to the composition and structure of the rock of which they are composed, and to the particular modifying agencies such as water, wind, temperature

changes, plant roots and so on which have acted upon them. These processes form part of the subject of Physical Geography, dealt with in another volume in this Series. In this book we are not concerned with the causes that have produced these landforms but with their effects on man's life and activities. These effects are so extremely numerous and complex that many whole books much larger than this have been written about them, but at the risk of oversimplification in order to compress them into a small space, I shall divide the effects of relief and structure on man into two broad sections: (1) the direct effects of the relief alone; (2) the indirect effects of rock composition, structure and relief, all acting together to affect man indirectly through the water supply. Climate is also, of course, a very important factor affecting the water supply, and it affects the relief as well. In any one example it is almost impossible to disentangle the effects attributable to group (1) from those attributable to group (2): if you build your house on a gravel terrace beside a river, do you do it because the gravel makes a drier foundation than the nearby clay, or to escape floods, or to be near a supply of drinking water, or for all these reasons together? But even if in any one example the direct and indirect effects are all tangled up together, we may still consider them separately.

Relief affects the positions of settlements and the use made of the ground. But relief is a relative affair. A clay knoll ten or twenty feet high is very prominent in the peaty flats of our Fens because it lies above all ordinary floods and serves as a good firm site for houses and farm buildings: in the hilly coffee country of Brazil it needs a rise of a hundred feet or so up the valley side to safeguard the coffee trees from the cold air draining down into the valley bottom: in the Alps a ridge of two or three thousand feet is just high enough to produce a clear-cut distinction between the thick damp forests on its cold northern slope and the vineyards, houses, grain and potato fields on its warm sunny southern face.

In general, we may say that in flat country very slight relief features are of importance mainly in relation to water, which is

the chief hazard at lower levels, whereas in hilly or mountainous country the relief affects both the water supply and the local climates and in that way has its most pronounced effect upon man. In the Fens, Upwell and Outwell are two of the longest villages in England, each a double line of houses winding for miles along the two banks of the old River Nene: the banks are only a few feet above the surrounding rich agricultural land but they afford the driest building sites available, and the river at the house doors formerly served for a highway. Go to Holland, or to the immense deltas of the Ganges and Brahmaputra in Bengal, or to the Yang-tse delta in China, and the settlements follow exactly the same plan, being long lines of dwellings between the winding sluggish river and the flat low fields on either side of its high banks. In Bengal and China they grow rice on the low fields, either by letting the river do the flooding and growing the rice in the water left behind, or by laboriously pumping water from the river over the banks, steering it carefully down, field by field, to the lowest parts of the saucer-shaped islands between the meshed river channels, and then laboriously pumping it back again into the river. In the Mississippi delta the same pattern of settlement is followed: the half-French inhabitants of the bayou country live in reed huts along the banks, growing fruit and vegetables in the drier parts of the flood plain and harvesting shrimps from the parts still under water. In all these areas so far apart and so different in many other ways, similar relief has given rise to similar settlement patterns.

In higher country with more pronounced relief it is not so much the danger from floods as the supply of drinking water that controls the sites of settlements, but another factor not met with in the flat lowlands is the effect of relief on climate. Mountains, and even low hills, cast shadows: in the sunless climate of the Lake District or Scotland, the farms are very often built on those sites in the valley where they will catch the greatest possible amount of sunlight during the year. Notice how often when you look up a valley in the Lake District in the evening or early

morning the farm houses are catching the low sunlight when much of the land between them is in shadow. In the Alps, the shady sides of the valleys facing north and east are left to forests and grazing grounds; the crops and the settlements are on the sunny sides facing south and west. This appears very clearly indeed in many photographs of Alpine valleys. In addition, the lee side of a high ridge is usually drier than the one facing the prevailing wind: in California, magnificent pine forests and running streams beautify the wet windward slopes of the Sierra Nevada and Cascade Ranges, but once pass the crests to the eastward, downwind, and we "drop again on desert, blasted earth and blasting sky." The bleak gravel plains of Patagonia, strewn with prickly, stunted, grey-green bushes and the bones of dead cattle, lie in the rain-shadow of the Andes, whose western slopes are wringing wet, covered with saturated forests so dense that dead trees rot where they stand, having no room to fall. We have no such startling changes within a few miles in this country, though the higher windward west of England is a good deal damper than the low-lying leeward east, and there are corresponding changes from farms devoted chiefly to raising oats, hay and cattle, with sheep on the hills, to farms keeping tractors instead of livestock and raising wheat and barley and sugar beet.

Other effects result from the rapid change in climate that you encounter as you rise in mountain country. As pressure falls with altitude, so does temperature: rainfall, on the other hand, may at first increase with ascent, but above a level that varies in different mountain chains, often roughly the level of the lowest passes that the wind can get through, it falls off steadily with height. At the higher levels, summer is shorter and cooler than in the valleys; the snow lies longer; the air is alternately brilliantly clear and dry, or thick with mist or snow. These changes of climate with height show in the vegetation and the use made of the land. In the upper Rhone valley above the Lake of Geneva vines thrive in the valley bottom on south-facing slopes, along with walnuts, cherries, apricots and other fruit

trees, tobacco, wheat, and all sorts of vegetables. A little higher the vines and apricots disappear, then the other fruit trees, except hardy apples and pears; wheat gives place to rye, the vegetables are reduced to potatoes and lettuces. On steep slopes and shady valley sides are woods of mixed deciduous trees; at higher levels these give place to dark stands of tall firs. The clearings at this level are mainly hay fields with here and there a potato patch. Higher still, the trees come to an abrupt stop at the edge of the high pastures, broad shoulders of the mountain covered with short grass and ablaze with flowers from the moment the snow melts, flowers which open, set seed, fade and ripen their fruits before the snow returns a month or two later. Higher still, the pastures yield to rock and scree with the hardiest of the true alpines tucked into tiny cracks of the cliffs or cushioning the slopes, and above these still is the perpetual snow.

The mountaineers of the high valleys have worked out ways to use all these zones with their different climates and products to the very best advantage. Each village commune owns land at all levels, from vineyards to high pasture; the village is at an intermediate level, and all through the spring and summer some of the people of the village are away from home, either down in the low country attending to the vines, or at the lower meadows in the fir-wood belt, making hay, or up at the *Alpage* or high pasture with the cattle, milking them and making stores of cheese or butter for the winter. The cattle are kept in the village in winter and fed on stored hay from the nearer pastures; as the snow shrinks back up the mountains in spring they are driven first to the intermediate pastures for a week or two, and then on up to the high Alp for the middle of the summer. Meanwhile, the grass they have eaten down is heavily manured and irrigated from the glacier streams, so that it then grows one or even two more good crops of grass which is cut and stored as hay. At the same time other members of the family have gone down the mountain to prune the vines, prepare the fields and sow the grain and vegetables in the valley lands, moving back to higher levels as the season advances, and going down again to the

valley for the harvest and the vintage. With autumn the cattle come down again from the Alp, the harvesters up from the valley, and as the crops are safely in, and the cattle snug in winter quarters in the village, the family is reunited for the winter.

This semi-nomadic life, which makes the very best possible use of the varied resources available, is known as *transhumance*, and is found, in a great variety of forms, wherever there are mountains. In Wales the sheep of the hill farms are moved about in somewhat similar fashion, close to the farmhouse for the lambing season, up on the mountain for the summer, the lambs down to the more protected valley grazings for their first winter and back to the mountain in the spring. In Spain and the Rhone delta, the sheep are taken to the mountains to escape the hot dry summer in the lowlands, a journey sometimes of as much as a hundred miles ; the sheep were driven along special rights-of-way in the old days, but now they are mostly taken by train. This transhumance is more than a little like the seasonal migration of city dwellers in the eastern United States to the seashore and mountains of New England and the Catskills in summer, or our own holiday migrations to the seaside or the mountains : both the sheep and ourselves make the best use possible of more than one environment.

Relief and Water Supply.

We saw in Chapter II how essential water was to animals, man included. All through his history man has made his home beside water, and the sites of most of our older towns and villages, even of single farm houses, are clearly chosen in relation to rivers, pools, springs or wells which formed the water supply of the original settlement. If there is no water to be had, either from the ground or from the rain, then there is no settlement ; save that nowadays, as technical skill has made it possible, settlements have sprung up here and there in waterless country because there was some natural resource valuable enough to be worth the enormous outlay necessary to bring in water from far away. The towns of the completely rainless nitrate pampa

of Northern Chile bring water in pipelines over the desert for a hundred miles or more from the snow-fed streams in the high Cordilleras. The mining towns of West Australia, Coolgardie, Kalgoorlie and Mount Margaret, with populations of 25,000 between them, bring water from Mundaring, 350 miles away. But it is only the great mineral wealth to be had here—another example of the influence of rocks on man—that has made it worth while to maintain these towns so far away from any reliable natural water supply.

However, many of our own large cities present problems in water supply just as worrying and costly as those of the desert mining towns, because there is seldom a natural supply of water close at hand which will be sufficient to provide a million or more people with several gallons of water each per day, apart from the even more stupendous quantities of water needed by many of our industries. Even if there are lakes or rivers available, our ingenuity has so far failed in most cases to get over the difficulties arising from the dangers of pollution by sewage, where so many people are crowded as closely together as they are in our towns.

In country districts, where until recently everyone relied entirely on local supplies of water for all purposes, the distribution of the population is clearly related to that of the water. In its turn, the distribution of the water is related both to the climate and to the composition and structure of the underlying rocks. With impermeable rocks such as clay, water cannot sink in; shallow surface wells or ponds can be made anywhere and will give a steady supply of water except in prolonged droughts. No very great catchment area is needed; a space 100 yards each way, even allowing for two-thirds of the water to run off or evaporate, would supply a hundred people or a large herd of cattle. Ponds, in early days, were often dug in clay country to get clay to burn into bricks to build the houses of the settlement: so in clay country villages and farms are spread everywhere, and each has its own pond, now often replaced by a shallow well with a pump.

Where the relief is more pronounced, instead of collecting

into ponds the water runs off in streams, and beside them the settlements are found. If the stream tends to dry up in droughts, as it may well do if it carries only the surface run-off, a small dam, easily built in a narrow valley, will save the situation. We find that exactly the same thing has been done, on a larger scale, by the towns in the west of England. Birmingham, Manchester and Sheffield use the water running off the impervious rocks of Wales, the Lake District and the Pennines, impound it in big reservoirs, and bring it where it is wanted through great acqueducts, just as a single farm may bring its water from a pond higher up the valley in a pipe.

Where the surface rocks are porous or full of cracks, in chalk, limestone or gravelly country, the rain sinks in rapidly after it falls, often to reappear as springs at a lower level. These rocks give dry country with little surface water, unless it is stored in reservoirs :

> " . . . No running streams delight
> Our broad and brookless vales :
> Only the dew-pond on the height,
> Unfed, that never fails."

So Kipling speaks of the South Down chalk hills, bare sheep country with few and remote farms, carrying their water from distant springs or relying on rain-water butts and deep wells : the settlement pattern is very different from that of clay country with its abundant surface water. Limestone often forms rough hilly country with all the rain water, except immediately after a downpour, sunk underground down pot-holes and swallow-holes, where it runs in the dark through labyrinths of caves to emerge at last as a broad clear stream. Since most of the surface is waterless, settlements lie on the springs and rivers, unless, as in the peninsula of Yucatan in Mexico, the underground waters are near enough to be reached by wells. Gravel country is often low-lying, near rivers, and so the water problem is easily solved ; since gravel makes good dry foundations many old villages and towns were originally built on gravel patches near the rivers, as you will see in the volume in this Series on Historical Geography.

All these examples show how the kind of rock we live on, as well as the amount of rain that falls, controls the supplies of easily-available water, and so the way in which man arranges himself and his dwellings over the land surface. Nowadays, however, much of our water in all parts of the world is drawn from out of the rocks at great depths, and it can only be tapped by modern methods and modern machinery; the distribution and volume of these underground supplies may bear no very obvious relationship to the present distribution and amount of rainfall over the surface, and the settlements dependent on them can be placed anywhere so long as it is convenient to bore a well reasonably near the spot. Water which may have been derived from rainfall of many years before, at a very great distance, is found in artesian basins, such as that which gives London some of its best water. The rocks that supply London with artesian water are the Chalk and the overlying Thanet Sands, sandwiched between the grey Gault Clay below and the London Clay above. These beds have been bent into the shape of the lower half of a long shallow funnel lying on its side, with its mouth to the east: the northern edge of the funnel is formed by the Chiltern Hills, the southern edge by the North Downs, and between the two the Chalk dips underground in a great sweep, overlain by the London Clay that keeps any local rainfall from seeping into it except along its exposed edges; the sea has flowed in over a part of the funnel mouth to give the wide estuary of the Thames between the Essex marshes and the north Kent coast. Wells sunk through the London Clay tap the water in the Thanet Sands and the Chalk, and because of the pressure under which it lay there it used, when released, to rise in the wells to a level above the ground surface, but overdrawing on London's water capital has caused the level to sink in the wells until now it is far down below the upper surface of the Chalk itself. At the same time the colossal weight of the overlying beds and presumably of London itself has caused the interstices in the rocks, formerly kept open by the water when under pressure, to close so that it looks rather as if London will never

be able to pay back the overdraft on her water account with the Chalk, and her underground supplies may eventually disappear almost completely.

However, if we do not take out of an artesian basin more than the water being supplied to it by rain on the exposed edges of the porous rocks, it can be of enormous benefit in supplying water to places in the centre of the basin which have insufficient rainfall. In Australia many of the interior grazing grounds have only been opened up since the artesian basins underlying them were discovered. Now stock can graze over hundreds of square miles of country with a very low rainfall, just sufficient to maintain the vegetation but not enough to provide surface water of any kind. The stock can be watered at the artesian bores, though much of the water is hot as it comes from the bore and too salty to be of any use for irrigating crops.

Crops need water as much as man needs it. Ever since man took to farming he has tried to improve on the unsatisfactory distribution of the free water he gets from heaven by leading water to his crops from more reliable and easily-controlled water sources such as rivers. Irrigation is coeval with agriculture. Hand in hand with it goes drainage, for in damp climates too much water in the soil may be as bad for the crops as too little. Hence arise innumerable devices for moving water from one place to another, running it by gravity from higher levels to lower ones when relief permits, or pumping it up from lower levels to higher ones when the relief is, from the point of view of the farmer, awkwardly arranged. Thus the Swiss peasant digs leats, running almost along the contours, to lead water from a stream high up in the valley out on to his hay fields on the mountain shoulder at a slightly lower level. To run the water over his field he blocks the leat with an axe-shaped slab of stone, and the water overflows and runs down the steep hillside to feed and stimulate a second crop of grass. The Egyptian fellah, the Dutchman or the Fen farmer, living at or below sea level, has to drain the water from his fields into ditches dug below the soil level, and from these pump it up into higher,

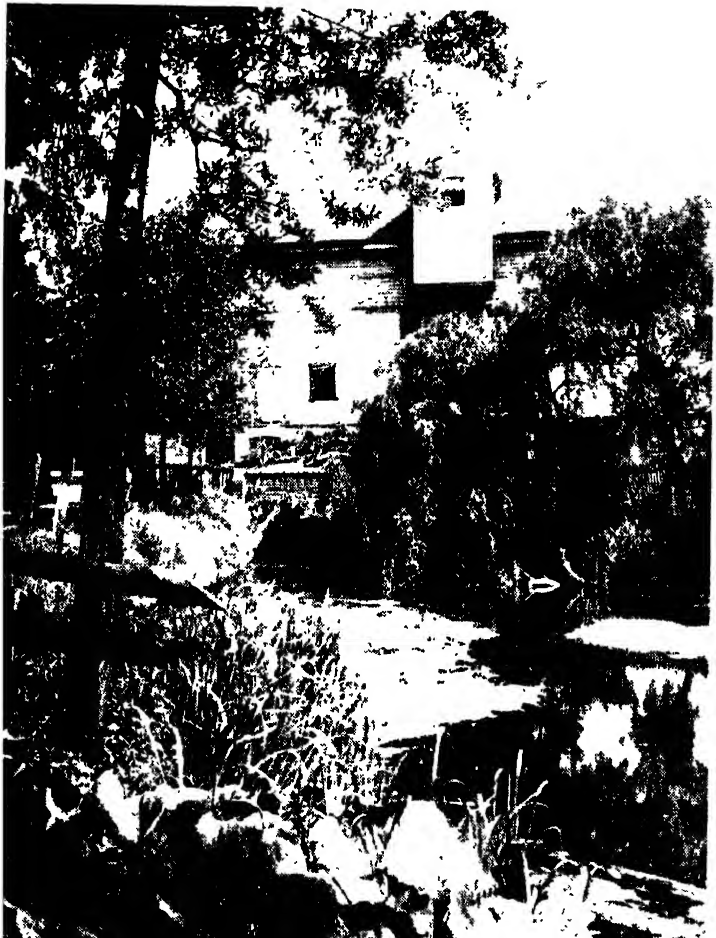
larger drains, and so in turn from these into the rivers or into the sea, letting it escape when he can by gravity at low tide. There is scarcely any farming country in the world where the natural arrangements for the distribution of water meet with the farmer's entire approval; everywhere the arrangements made by man to improve upon it repay careful study by a Biogeographer. They involve very careful and exact fitting of man's requirements to the conditions of climate and relief in the area concerned. Next time you take a walk in the country pay particular attention to the water and drainage systems, both the drinking water supply for the villages and farms and the water supply for livestock in the fields; there is little irrigation in this country because we generally have abundant and reliable rain, but the drainage systems for getting the surplus water away from the land are extremely elaborate in many areas. I think you will be surprised, if you have never before studied it in the field, to discover how much of the surface water in this country, especially in the arable districts, flows in artificially constructed channels, each an example of careful adaptation of man's work to his physical environment. It is the rare stream that rises spectacularly in a never-failing spring; the great majority take their humble beginnings in field drains and draw most of their tributary water from man-made drainage ditches along the field borders.

Water is one of the easiest things in the world to move about, as we most of us discovered as children playing with the salt streams running down the sands as the tide fell. Underground water supplies derived from springs and wells and artesian bores are not so easily rearranged as surface water, but wherever the population begins to increase beyond the power of the local supplies to support, man begins to redistribute the water into a pattern more convenient for his immediate needs. The physical environment of rain and rock forms the framework to his final picture, but within those limits he can do pretty much as he likes so long as he is prepared to pay for it. What he seldom realises, bemused as he is with admiration for his own technical skill as a water engineer, is that his actions in turning the water

out of its natural path may produce enormous and often very destructive effects on the general environment. Great cities generally lie in the plains, which are ill-supplied with good clean drinking water. Water is brought instead from hill streams many miles away: the watershed of the basin draining artificially to New York is four hundred miles, and that of Los Angeles eight hundred miles, away from the city that consumes the water, and as the city grows it sucks more and more natural waters, on the surface or underground, into its maw. These waters are withdrawn from the lower reaches of the rivers they formerly fed, thus diminishing the flow, especially in times of drought, lowering the water-table, causing silting and other troubles, while above the point where the water is tapped, reservoirs may raise the water-table and change the local climate, drown great areas of fertile land, and entirely alter the natural habitat for hundreds of species of wild plants and animals. The water withdrawn, after a long journey in pipes and often with the addition of all sorts of chemicals, to turn it from what water engineers so delightfully describe as "raw water" into a fluid safe for our citizens to drink, eventually returns to the open air polluted with sewage, chemicals and industrial wastes, poisoning the life of the stream into which it is poured, substituting waxy sewage residues for the clean sand and mud of its bed, and altering for the worse the habitat of all the living things, man included, along its banks.

At the same time, the city is, as we have seen, sucking up ground water, often faster than it is being replenished by the rain on the distant outcrops of the water-bearing beds, and altering the water-holding capacity of the rocks beneath it. Not only this: the acres of metalled roads and house-roofs prevent the rain that falls from soaking into the rocks below the town, and instead pour it as it falls, smoke-blackened and choked with street rubbish, through drains and outfalls back into the polluted rivers that carry the sewage effluents and factory wastes to the sea.

This is no exaggerated picture of the way we have wasted our



(*Photo: Raphael Tuck & Sons, Ltd.*

AN UNPOLLUTED RIVER

(Photo by Frank Woodward by courtesy of the British Field Sports Society.

AN EXAMPLE OF RIVER POLLUTION

heaven-sent waters: how many streams flowing through even quite small towns would you care to bathe in when the water is low in summer? The sun, bacteria, hosts of natural scavengers of all sorts, both plant and animal, do their best to retrieve the mess we have made of so many of our streams, but they cannot do it all, and it is doubtful whether the rivers of this country can ever again get back to the condition they were in at the beginning of the last century, when the apprentices of London petitioned against being fed too often on Thames salmon. It is known that lakes which are used as sewers for the towns on their banks fill up more rapidly, lose their more desirable kinds of fish, and deposit on their banks rank slimy mud instead of clear sand and pebbles: workers in this field have come to the conclusion that once these changes have taken place they are irreversible, and the lake will never again be the clean, sparkling reservoir of crystal water that it was before man tampered with it for his own ends.

So when next you look at the Irwell, or the Roch, or the slimy ooze of the Thames banks by Tower Bridge at low tide, recall that our not-far-distant forbears caught salmon in these rivers; that much of their dead, fetid water has been taken from clear unpolluted upland streams, or sucked up from irreplaceable underground stores, and brought to this horrible pass by man, and ask yourself whether man's use of water in towns, in spite of its superficial convenience and technical perfection, is really very efficient as a permanent adaptation to his physical environment. What will happen to London and Birmingham and Manchester if we have another drought like that of 1711?—what will their millions of inhabitants drink and what will become of all their sewage?—yet the whole countryside away from the towns is a meshwork of drainage channels dug to get rid of too much water on the land. Down to the sea in the sewage go thousands of tons of minerals and organic wastes, at a time when we are short of food all over the world and year after year are failing to balance the minerals taken out of the soil in crops by equal amounts put back in the form of fertilisers or manures. And throughout the whole problem runs the ever-recurring motif of

conditions changed for the worse almost everywhere: land needed to grow food sterilised under water in reservoirs: water-tables raised or lowered at the will of town-dwellers without reference to the country-dwellers immediately affected by them; silted streams, polluted waters, falling wells, failing springs and dying fish.

We must have water to drink, if we are to keep alive at all, and nowadays there are seldom any insuperable technical difficulties to prevent us from putting the water exactly where we want it; but as biogeographers we must think of other things besides our own direct needs. Water, whether as rain, a river, a pond or a spring, plays an immensely important part in the life of a landscape; it is essential not to man alone but to millions of other living beings, plants and animals, as well. By meddling with the natural arrangement of the water supply, man may very easily upset a host of delicately adjusted relationships among all these living things, and in turn between them and himself; the disappearance of the Thames salmon is but one conspicuous example of such an effect. To use natural water supplies well, by the biogeographer's standards, men must not only acquire the good clean water that they need for themselves, but in getting it they must pay due heed to all the effects they thereby produce in the whole of their physical environment. If the bad results they produce—silted lakes, polluted streams, dead fish, falling water-tables—outweigh the good ones, they have, in the biogeographer's eyes, made but an inefficient adaptation to the conditions of their environment.

Here is a tough problem on which to cut your geographical teeth: how can man in this country, living as he prefers to do in curious clots and swarms of population here and there, adjust himself to a natural supply of water which is spread almost uniformly everywhere by the rain, and concentrated locally into streams, rivers, lines of springs and layers of water-bearing rocks? How can he do this with the least possible damage to his natural physical environment? If that is too big a problem on which to start, consider you own local water supply in the

light of its relations to the geographical conditions of climate, relief and rock structure. How have these things influenced the supply, its source, amount, and the way in which it is obtained and used? How, in turn, have the technicians and engineers who made the water available to you in pipes and taps, dealt with the natural surroundings? Go and look at your local water-works, reservoirs, streams, wells or pump, and at your local sewage disposal plant, and find out. And do you, as a geographer, trying to find a true balance among all the factors of the environment, think that the water engineers have made a good job of the biogeography of water supply, or only of the technical side of it? Have they neglected the claims of other interests, beauty, wild plants and animals, and the hundred and one other features of the environment? Next time you turn on the tap, picture the water that comes from it as it indeed is, a gift fallen from heaven and turned by man to his own use. Has he used it well, not wastefully, or selfishly, content with what comes freely and naturally year by year, not prejudicing his children's supplies to gain more for himself? As a practical Biogeographer, if you do not know the answers to these questions where your local water supply is concerned, go and find out. And if you are dissatisfied with what you find, if you think your local water supply and sewage systems show bad adaptation to the environment, try to put your Biogeography into practice and get at least the worst of the abuses removed.

CHAPTER V

MAN AND HIS FOOD: SOME GENERAL IDEAS

WE saw in Chapter II that if any animal is to go on living and moving and reproducing it must get from its environment three things, oxygen, food and water. Oxygen is abundant almost everywhere, but severe limitations are imposed on man's activities in the few places, such as high mountains, where it does begin to diminish. The supply of water we discussed in the last chapter, and saw how its discontinuous distribution over the earth limits man's spread in some places, encourages it in others, and makes him devote much thought and labour to the task of rearranging the natural supply of water more conveniently for his needs. We also considered how he is affected by the rocks he lives on, which he makes into tools and builds into houses in a deliberate attempt to live more comfortably in all sorts of different environments. We have seen, then, how his physical environment supplies him with two of his essential bodily needs, air and water; how it affects him physically through his body and stimulates his brain to think out ingenious ways of using the raw materials lying to hand in the rocks, and in the plants and animals that grow and live on them, in order to make his life less precarious and more pleasant. But so far we have not considered his third necessity, food, and the ways in which he gets it also from the environment.

Man has to rely on plants to elaborate food for him from inorganic salts and gases, and hence any discussion of food at once leads up to the problem of man's relations to the other living things about him, the plants that elaborate the food, and the animals that either concentrate it for him into meat and milk, or those that eat the food he had intended for himself and so come into competition with him; these last are the animals

against which man wages a war of extermination, disdainfully classing them all together as pests and vermin. The inter-relations between man, his food, the animals and plants which produce the food and eat it or each other, and the physical environment which ultimately decides what kind and quantity of food will be available, are extraordinarily intricate and fascinating. In this and later chapters I shall try to follow up one or two of the threads that can be traced in this complicated fabric of many interwoven strands, and I hope that as I do so the reader will be able to build up in his mind as we go along some sort of picture of the whole elaborate pattern of the fabric. Let us consider first the relations of animals to plants in the matter of food.

Plants make the foods, animals eat them: that is our starting-point. The rose and the hawthorn make starch in their leaves from carbon dioxide and water; vegetarian animals, such as green-fly and hairy caterpillars, eat the leaves; a chiff-chaff eats the green-fly on the rose, and a cuckoo the caterpillars on the hawthorn, and a frugal Italian peasant snares both birds and puts them in a stew. Being omnivorous, unlike the birds or the insects, the peasant can add vegetables from his garden to his stew, and so consumes a mixture of bits of geographical environment from all sorts of places that almost defies sorting out. We eat, let us say, pork from milk-fed Danish pigs; but the cows that gave the milk ate grass and oil-cake, both vegetable foods; we eat eggs from hens that ate grain, a plant again; or we eat fish that ate smaller fish that ate still smaller fish and little crustaceans that in turn ate the tiny unicellular green plants called diatoms that are the ultimate food of all creatures in the sea. Here we have a series of strings of organisms, bound together by the most intimate links, each being eaten by the next in the series; such strings are called "Food Chains," and always begin with a green plant of some sort and end with a fairly large animal which does not apparently serve as food for any other. We can express these chains like this:—

Rose-leaf⟶green-fly⟶warbler⟶man.

Grass——→cows——→man.
↓
milk——→man.
milk——→pigs——→man.

Diatoms——→vegetarian fish and crustacea } ——carnivorous fish——→man.
——————————→man.

Each member of these food chains, with the exception of man in the second chain, is bigger than the one below it in the series, the one which it eats. The pig, which is an apparent exception, is an omnivore like man; in nature, of course, it would not be living on milk but on a largely vegetarian diet. This relation of size between the eater and the eaten is found all through nature, with few exceptions: foxes are larger than mice or rabbits, cats than rats, killer whales than penguins which in turn are larger than shrimps, and so on. However there is one large class of animals which habitually prey on, though they may not kill, animals larger than themselves; these are the parasites. We ought really to continue our food chain past man to his parasites and their parasites, thus:—

Rose-leaf——green-fly——warbler——man——lice——protozoa——bacteria,

and in addition there ought to be branches off from each link of the chain, because every organism has its own parasites, down to the bacteria, which appear to be preyed on in some way by mysterious entities called bacteriophages, which are presumably the very last link in every chain. Other animals, not parasites, by hunting in packs like wolves or driver ants, or by terrorising their prey like weasels and snakes and skua gulls, manage to feed on, or in some way get their food from, animals as large as themselves. Man has copied this notion in many of his hunting techniques. The blackfellows in Central Australia, instead of fascinating an emu as a snake or a weasel does a rabbit, until it is unable to move, put a vegetable poison in the smaller water-holes, so that the emu becomes stupefied and cannot run away; the pygmies of Central Africa combine in packs like wolves to hunt elephants with their puny weapons; the bee-keeper, sub-

jugating his bees with smoke while he steals the hard-won honey they have stored, is using much the same technique as a skua gull, which frightens other gulls into disgorging the fish they have caught for themselves.

Apart from these exceptions, and leaving parasites out of account until Chapter XI, there is generally an upward limit to the size of the food an animal eats. There is also a downward limit, reached when the portions of food become too small to be worth the trouble of collecting, unless the animal has some kind of drag-net for the purpose like the plates of the whale-bone whale, or else is prepared to spend a great deal of time simply collecting food, as the bee does collecting pollen for her brood. Pollen stands to the bee in the same sort of size relation as wheat grains stand to ourselves: both involve laborious harvesting methods. Animals prefer food of a reasonable size: foxes prefer rabbits and fowls to mice, unless mice are very abundant and therefore easy to collect: as every housewife knows, when in a hurry to prepare a meal you choose a cabbage from the garden in preference to peas. These tastes in size of food are one of the bonds that tie wild animals closely to a particular environment and a particular way of life. Man has beautifully accommodating teeth and digestion to help him eat foods of all kinds, and he has learnt to prepare foods of all sizes; thus he has emancipated himself in yet another way from the tyranny of physical adaptation to particular environments and particular foods that holds wild animals so firmly in its grip. One day we eat a meal of shrimps, though some people think them beyond the lower limit of useful size in food, and the next day whale, having, like the lady in *Punch*, first cut our whale into dainty pieces. With the shrimps we eat bread made from grain, again near the lower limit of useful size and requiring much collection and preparation before it can become satisfying food; and with the whale we eat potatoes or the prize marrow from the local show. Our capacity for dealing with food of all sizes, as well as of all kinds, plays quite an important part in allowing us to live in so wide a variety of conditions.

In nearly all food chains the animals that form the lower links in the chain are not only smaller but also more numerous than the animals that prey on them. The smaller an animal is, as a rule, the more rapidly it increases in numbers; it leads a shorter life, matures more quickly, and produces more young than a larger animal; it has been calculated that if food were available, the children, grandchildren and subsequent descendants of a single protozoon would weigh more than the whole earth inside a week. Anyone who has kept guinea pigs, white mice or rabbits knows that though they cannot quite compete with the protozoon they put up a stout attempt to do so. The small animals, in fact, produce a large excess of population over the numbers of breeding stock needed to keep the species alive in the absence of predators, and on this margin the predators live. The predators have a smaller margin of numbers on which the species next higher in the food chain lives in turn, and so on. This arrangement of numbers of animals in a food chain, with the smallest and most numerous at the bottom and the fewest and largest at the top, is spoken of as the Pyramid of Numbers, or the Eltonian Pyramid after Charles Elton who first called attention to it as a fundamental feature of the relations between living things and their environment. Man, apart from his parasites, is at the top of a large number of such pyramids, but when he is still a hunter and collector like the other animals he, like them, cannot increase in numbers beyond the margin provided by the species below him in the pyramid. If he does, he will starve. Hunting peoples, therefore, are generally few in numbers, and spread over great stretches of country. Their relation to the animals which serve for their food is suggested by the following table, given by E. H. Graham, of the numbers of breeding animals on a square mile of range land in Arizona: as we shall see later, man could occupy about the same position in the table as the coyote, if he were relying solely on hunting for food.

POPULATIONS OF BREEDING ANIMALS ON 1 SQUARE MILE, SANTA RIT RANGE RESERVE, ARIZONA.
(after Leopold: *Game Management*, Scribner's, 1933.)

Number	*Species*
1	Coyote. (Predators.)
2	Horned Owl. (Predators.)
2	Redtail Hawk. (Predators.)
10	Blacktail Jackrabbit.
15	Hognosed and Spotted Skunks.
20	Roadrunner.
25	Cattle (over 1 year old).
25	Scaled Quail.
25	Cottontail Rabbits.
45	Allen's Jackrabbits.
75	Gambel Quail.
1,280	Kangaroo Rat (*Dipodomys*).
6,400	Wood Rat (*Neotoma*).
17,948	Mice, spermophiles and other rodents.

It may be noticed here that these vast numbers of small birds and mammals, vegetarians and insect eaters, support as predators only four birds of prey and one coyote.

Hunters, such as the Bushmen of the Kalahari Desert or the Pygmies of the Central African forests, keep their numbers small enough for the food supply by getting rid of unwanted children in various ways, for children not only require feeding but are a hindrance when the group must move about rapidly in search of food. These peoples may abandon or kill the members of the group who get too old to do their share of the hunting: the Fuegians explained, according to Darwin, that they killed their old women before their dogs in time of famine because "doggies catch otters; old women no." The South African Bushmen and Australian blackfellows abandon their old people in times of drought when game is scarce and only by rapid movement can the younger people find enough to keep alive.

Nature, through food, exercises a stern control over the numbers of men that can live in a given environment, so long as they live like the animals on wild foods only.

But once man has learnt to grow his own food the picture changes. The base of the pyramid can now expand and so the number of men at the top of the pyramid increases too. Ever since the Neolithic Age man has been evolving more and more perfect devices to allow him to cultivate more and more land and so get himself more food. The series of tools, from the hoe and digging stick by way of the plough, one of the most fateful of all inventions, to the rotary cultivators, seed drills and combine harvesters that we take for granted today, bears witness to his search for ways to increase his food supply with the least possible labour. All through history the numbers of men have depended on the food supply, which in turn has depended on the amount of food that one man can grow, and that in its turn has depended on the kind of crops he grows and the tools he has to till the soil with, all factors within his own control; but as well it has depended on the climate and soil, in other words the physical environment, which he cannot control, so that he must deliberately adapt his methods to it. In the final analysis it is this physical environment which, through the food supply, controls the numbers of men that can live on earth.

However there are other important factors that must be taken into account in considering the numbers of mankind in relation to food supplies. Man is not only at the apex of a pyramid of numbers based on his crops and including in its middle storeys his domestic animals; he is also at the apex of another pyramid, an inverted pyramid, of parasites. Some are large and not very numerous, like hookworms, fleas and lice; others are extremely minute, incredibly numerous and very important, such as the malarial parasite, the cholera morbus and the bacillus of plague, or the still smaller viruses responsible for the common cold and influenza. These, by preying on him, control man's numbers directly, but an army of other parasites also preys on his crops and his domestic animals and so helps indirectly to control his

numbers through his food supply. At the same time that he has worked at increasing his food supply by improving his tools, man has worked at reducing the damage and loss caused by these parasites that prey on him and his crops and animals and so tend to keep down his numbers. He has, in fact, as some might think, been altogether too successful in this effort, because there is no doubt that the enormous increase in world population made possible by progress in medicine during the last century, combined with the fabulous increase in the output of food, has thrown a cumulative strain on the soil, the ultimate source of all food through the plants that grow on it, so great that it shows ominous signs of breaking down under it. To this exceedingly pressing problem in human geography we shall return in Chapters VIII and IX. Here we note only that man has deliberately increased his own food supply by growing more crops and raising more herbivorous animals, and at the same time has reduced the toll taken by parasites, so that there are now incomparably more men in the world than there could ever have been had they all remained hunters and collectors of wild food like other animals.

It has probably occurred to you, at this point, that if the numbers of men in the world increase so also does the food supply for man's parasites. Not only that: if man increases his own food crops, he increases at the same time the food of a host of other parasites and predators that live on them just as he does himself—rats, mice, Colorado beetles, sparrows, and a vast array of plant pests such as moulds and rusts, for example—and in turn the food supply for their parasites is increased, and so on. Man has been trying to increase only his own food, but in doing so he has upset the delicate balance between food and eaters in all sorts of ways, and in particular has encouraged "vermin," the animals that by preference live on his food and on him, and "pests," the plants and animals that live in his fields and on his crops. The curse of Adam, in fact, he brought upon himself by upsetting the balance of nature, when he took to eating plants of his own growing, after an unfortunate ex-

perience with wild apples, instead of living upon game. We shall be continually running up against this problem, which is more fully treated in Chapter XII, of the disturbance created in the balance of living things, all dependent in one way or another on each other, by man's efforts to increase his food supply, to spread into new environments, and to live more and more comfortably in ever-increasing numbers.

There is another complication that arises also at this point. Man has learnt to increase his food plants and animals to a point now limited only by the supply of gases, water and salts for plant food in the air and the soil: he has gone a good way towards learning to reduce the numbers of the abundant and ever-increasing army of predators and parasites that hamper his efforts in the field and undermine his own health; but he has not yet learnt to control his own numbers by any but the crudest methods. Moreover, his numbers increase ever more rapidly; for a population increasing at a given rate, the bigger the population grows the more babies are born each year, and so the situation gets steadily worse.

The natural checks on a growing population are disease, famine, and war. We have learnt to check the effects of disease in reducing population, particularly its effects on very young children, so allowing more of those born to grow up and have children in their turn; we have hitherto managed to control famine to a great extent because by ships and railways we can distribute food better and more quickly than we used to be able to do, and so we avoid great local scarcities due to floods or droughts. War we have not learnt to control, but it appears to be the least effective of the three methods as a population check.

Meanwhile, the numbers of mankind are beginning to increase at a fantastic rate, by many millions a year. It is true that in the more advanced industrial countries obscure influences are at work which are slowing down the rate of population increase or even stopping it altogether. Urban life seems to be one of these, as town populations never increase so fast as rural ones

and often fail to maintain themselves, so that they have to be steadily recruited from the rural surplus. Education seems to be another possible factor, and a very important one, as it will be the one on which we shall need to rely if we are ever voluntarily to keep our numbers down to a level where we can all be well fed; the rate of increase is considerably smaller among the wealthy and the professional classes than it is among the poorest section of the population, who, judged by the criterion of income-earning capacity, are less well educated. But none of these possible factors much affects the teeming populations of India and China, which are only at the beginning of the spectacular rise in population made possible by advances in medicine and the lengthening of the expectation of life that results from them. There seems no escape from the conclusion that when the limit of productivity of the soil is reached, and there is little doubt that that will be very soon, these populations will have to be controlled either by famine or by disease, unless before then man learns to turn his attention as successfully to solving the problem of controlling his own numbers as he has already done to the problem of increasing his food supply or creating atom bombs.

I noted earlier man's curious tendency to collect in swarms and clusters of population in certain areas to the apparent neglect of others. There are generally good geographical reasons for this arrangement, reasons which are often lumped together by saying that "the environment is more favourable" in the congested places. But we ought to be quite sure what we mean when we say this. For instance, an environment favourable for a man who lives by hunting is not necessarily favourable for one who is a farmer or a breeder of cattle, and vice-versa. Few environments are favourable enough for hunters to allow them to exist in any large numbers in any one place, because the rate of increase of big game animals is slow and the smaller animals, living on the natural vegetation, cannot increase beyond the limits set by that in turn. E. H. Graham estimates that it requires 12½ acres of range land in the west of the United States

to support a small deer, or 40 acres for a large one. Hunters have an astonishing capacity for eating vast quantities of meat in a short time and then starving between whiles: two Australian aborigines have been seen to eat 50 lbs. of kangaroo meat between them in an afternoon, and three Lapps can finish a reindeer at a sitting. Let us suppose that one small deer will last a hunting family of four persons for four days: then they will need about 90 deer a year, which in turn will need over 1,125 acres to support them. This works out at a population density for the hunters of just over two persons to the square mile; but we have not allowed for the area of range needed to support the breeding stock of the deer, so that the density of the hunters will probably not exceed about one to the square mile. Since the land surface of the world is about 56 million square miles, if man was still only a hunter his total numbers could never have exceeded at most about 56 million; certainly they were very much less than this, since about 22 million square miles of the land consists of either lifeless icy wastes or almost equally lifeless dry deserts. Also we have left out of account all other predators; wolves, lions, tigers and so on must take a heavy toll of the numbers of their prey, and this consideration further reduces the number of men that a given area could support. On the whole probably not more than 20 or 30 million men at the outside could live on the earth, if they relied solely on hunting and collecting wild foods. Today the world contains about 2,000 million people, which gives a rough measure of the extent to which man has increased his food supply by becoming a farmer. But the areas of land suitable for farming are much smaller than the total land surface of the globe: Fawcett calculates that, after we have eliminated areas unsuitable either by reason of climate or of relief, only 30 per cent. of the total surface, or about 17 million square miles, is suited to cultivation. This gives each member of the earth's population at present only just over 5 acres of cultivable land on which to grow not only all his staple food, but all the raw materials such as cotton and wood, and the luxuries such as wine and meat, that he uses as well. More

optimistic estimates raise the figure to about 8 acres, but even so the contrast with the square mile or more needed to support a hunter is very striking. However, the world's population is not spread evenly; in agricultural countries such as India and China we find millions of persons existing on only a fraction of an acre apiece, whereas those like ourselves who are fortunate enough to have a varied and abundant diet probably draw on the produce of a good deal more than our allotted 5 to 8 acres.

These denser populations are supported only by heavier production of food from a small area. An acre of good crop land produces hardly enough wild game to feed a man for a day a year, but it may produce one ton of wheat, or two tons of rice, or eight tons or more of potatoes, and these amounts of vegetable food will feed quite a number of men. If on the other hand they are used to feed animals first, and then the men eat the animals, the acre will not feed many more men than if it were devoted to wild game only. Animals are wasteful converters of food: Russell Smith states that to make one pound of meat requires an amount of grain which would make eight to fifteen 1-lb. loaves of bread, or the equivalent amount of grass, grown on an area much greater than that needed for the grain.

For this reason the really dense farming populations, living on the produce of the land they themselves cultivate and neither buying nor selling much other food, are almost purely vegetarians. The peoples like ourselves with more land to spare (for we grow our food on a very large number of acres in countries such as Canada, Australia and the Argentine as well as on our own land at home) live on a mixed diet of both plant and animal foods, but the uneconomical animal is always the first to go when food begins to get scarce, as in war time; the scarcity is due in part also to an actual reduction of the numbers of acres on which we grow our food, because we have to reduce the amount of food imported from overseas.

There seems no escape from the conclusion that the ever-increasing pressure of population on the available land of the

world, resulting from the uncontrolled increase in the numbers of men on earth, will drive us steadily towards a more and more vegetarian diet, until perhaps real famine will overtake us and reduce our overgrown population. This trend has already begun; it has been very conspicuous during and since the war, but it was there already at the opening of this century. Improvements in agricultural science may postpone the evil day on which we all become obligatory vegetarians, possibly without even cheese or eggs to enliven our diet. Chemists may learn to make foods from indigestible and unpromising materials such as sawdust, but the doctors at the same time will be busy trying to increase the expectation of life still further, and the politicians will be endlessly trying to raise the birth-rate. Where and how will it all end? The limiting factor, in the last analysis, is the total plant food that we can produce, an amount which in turn is controlled by the physical factors of area, climate and soil, in other words by the physical environment.

Before passing on to the next chapter there is one point that I should like to make quite clear. I have left entirely out of account in this discussion of man and his food the economic factors that complicate the question still further. They are dealt with fully in the book in this Series on Economic Geography. They are of enormous importance in ordinary life, and any plan to improve the ominous world food situation which I have outlined above must take full account of them, because little food is going to be produced, or transported, or bought and eaten, unless the grower, the transporter and the consumer are sure that the transaction is to their advantage. But I am here concerned solely with the biogeographical side of the question, the inescapable physical and biological bonds that tie together man and animals and plants, and in turn tie the living things to their physical environment. These are apparently less directly practical questions than costs of production or standards of living, but they are in many ways more fundamental. The economists have shown no greater skill than the politicians or the biologists at altering the rate of population

growth, and an empty stomach is apt to be a more convincing argument to its owner than an empty purse.

It may be argued that with our scientific knowledge we could now grow crops anywhere at all on earth, taking electric radiators and sun-ray lamps to the Arctic as the Russians have done, or distilling water from the sea to grow plants by hydroponics on barren coral islands; it appears that the limits to what we can do in these directions are not technical but economic, a matter of cost and not of physical impossibility. This is true. When atomic power becomes abundant and cheap we may suddenly find ourselves able to use for food areas hitherto considered physically hopeless, and so may give ourselves a breathing space in which to learn better how to control our numbers and how to live and let live. But by that time we are just as likely to have destroyed the whole human race by the same means, and so I shall leave these apparently remote possibilities of indefinite increase in numbers out of account. At present, physical limitations have the last word; the sun and the rain, seed-time and harvest, hunger and love, are older than profit and loss, and will outlast them. Even in Utopia, our animal bodies will still need to be fed.

CHAPTER VI

MAN AND HIS FOOD: (2): THE PROBLEM OF FAMINE

IN this and the following chapters we will deal with some of the other ways in which man is affected by the amount and kind of food that he can get from his environment. I am limiting myself in this book almost entirely to the biological effects of food and its apparent effects on the distribution of mankind over the world and on the physical efficiency of various peoples. There are vast numbers of other effects which we must leave out for lack of space, but I shall just mention some of them here.

The kind of food we eat is probably far more a matter of habit and tradition than of deliberate choice of physiologically suitable diets: most of us prefer, if we can get it, even on a hot day, a large slice of roast beef to a salad, and we all feel defrauded if we cannot have an iced cake to celebrate a birthday or a turkey for Christmas. In all communities, from the most primitive to the most sophisticated, tastes in food are conservative. Some peoples regard as delicacies foods that others find utterly repulsive. We shudder, most of us, at the Chinaman's birds' nests, or eggs a hundred years old, or the Icelander's pickled whale blubber and blood pancakes, yet we prize half-rotten grouse or cheese, and we avidly drink milk, which the Chinese consider with some justification a disgusting food. Among hunting and collecting peoples even the few foods provided by the environment are not always eaten. The reasons for this are sometimes dislike, or ignorance; the Fuegians seem never to have adopted as food the few edible plants that grow on their desolate coasts, and we ourselves in this country seldom use more than one or two of our many kinds of edible fungi. More often certain foods are not eaten because of social or

religious taboos, which may be pure fads, like many much-publicised "diets," or may have been originally imposed for good reasons, though the idea of what constitutes a good reason varies enormously from people to people. The prohibition of pig meat by both Jewish and Mohammedan law had a sound hygienic basis, because the pig is the scavenger of the eastern countries where this law originated, and is also the host of a number of extremely unpleasant parasites capable of infecting a man who eats an infected pig. The cow is held sacred by Hindus and must never be deliberately killed nor may its meat be eaten. This tradition is said to have arisen in the far distant past, when at times of scarcity cows, with their capacity for turning the most uninviting dry herbage into milk, were all that stood between the people and starvation. Such food habits, sanctioned by tradition and religion, are very tenacious, and remain to complicate man's relation to his environment when other conditions may have changed completely. The Jewish prohibition of pork, excellent in the unhygienic ancient East, is an extra difficulty to contend with in rationed England; the Hindu worship of the cow has made it vastly harder to produce enough food in India for the people themselves, for this already over-populated country contains, as well as its people, about one-third of all the cattle in the world, and they too have to be fed, however inadequately, from its impoverished soil.

Tastes and tradition in diet change very slowly, and are responsible for many of the troubles that beset administrators trying to plan a good rationing system. Changes can be brought about after a time by high-pressure advertising or propaganda, in a literate community or in one sufficiently advanced to possess radio sets; in an illiterate one tastes in food hardly alter at all, even in times of stress such as famines. "They clamoured for rice," says Kipling, describing attempts to relieve a famine in South India by distributing wheat, "unhusked paddy, such as they were accustomed to—and, when they found that there was none, broke away weeping from the sides of the cart. . . . In vain the interpreters interpreted; in vain his two policemen

showed by vigorous pantomime what should be done. The starving crept away to their bark and weeds, grubs, leaves and clay, and left the open sacks untouched." In cases like these, however, it may be found that people who have lived all their lives on one kind of food such as rice are actually unable to digest a strange food such as wheat or millet, which acts on them almost as a poison. But it is an important fact for the geographer to bear in mind, when considering how people can best adapt themselves to a given set of geographical conditions. It is easy to say that they ought to change their diet to one better suited to the climate or to their economic circumstances, but it is a very difficult thing to make them do it, even under compulsion. It is easier to create a black market in traditional and favourite foods than to get people to live on other foods, however good for them in theory, that they find unattractive.

In considering a diet from the geographer's viewpoint, as well as from the dietician's, the first things to notice are that there must be enough of it, and that it must be of the right kind. These two requirements are not always separable in practice. A sufficient diet provides enough energy for us to carry on our essential bodily activities such as breathing, the steady beat of the heart, digestion, and the repair of the body's tissues. However, if we are to do much muscular work we need more food to give us the extra energy necessary to use our muscles as well.

We all know that the energy supplied by a diet is measured in Calories, one calorie being roughly the amount of heat needed to raise the temperature of one pound of water by 4° F. If we burn a lump of sugar or a piece of fat in the air it gives off heat; if we burn it as food in the body it gives off slightly less heat, but does it more slowly. This process produces the energy needed to keep us alive and our bodies warm. Our main foods are classified as carbohydrates and fats, which both contain only the elements, *Carbon*, *Oxygen* and *Hydrogen* in varying proportions, and proteins, which contain *Nitrogen* and some other elements in addition to the first three. The calories supplied

by these three kinds of foods are shown in the table:—

1 oz. of Fat supplies	275	Calories in air,	255 in the body.
1 oz. dry Carbohydrate supplies	120	„ „	113 „ „
1 oz. dry Protein supplies	120	„ „	113 „ „

Thus, weight for weight, Fats are more than twice as good a fuel as dry Carbohydrates such as starch, or dry Proteins such as dehydrated lean meat or dehydrated white of egg. Of course the foods we eat, such as bread and meat, have in them, besides, a *great deal of* water which is of no use at all as a fuel; the calorific values in the table refer to absolutely dry foods such as dehydrated meat or mashed potato powder. Fat, however, in the form of oil or cooking fat, has no water at all in it, so that it is an extremely concentrated fuel for our bodies. There is thus a sound physiological reason for the Eskimo's love of fat, living as he does in a climate in which it must be very difficult to keep warm; Eskimo babies are said to prefer a strip of fat blubber to sweets, and in the extreme cold of the Polar Regions even the most fastidious explorers begin to acquire a taste for raw fat.

Since growing also takes a lot of energy, as well as needing large amounts of material to build up into new flesh and bone, all of which have to be supplied by the food, children need much more in proportion to their size and weight than adults; infants need forty or fifty calories per pound of body weight per day, adults only fifteen to twenty, and old people less than fifteen. A child weighing five or six stone, therefore, may need just as much food as either of its parents, and more than its grandparents; it is this fact which underlies many of the tragic effects of deficient diets in stunting children at a time when they need so much more food in proportion to their body size than adults do.

As far as energy requirements alone are concerned, the calories needed could be made up by eating any kind of food. If you were to eat nothing but lean meat, for instance, like some hunters do, you would need six or seven pounds of it a day to get enough

calories; Canadian canoe-men, if getting no other food, stipulate for eight pounds of meat a day. If the meat is rather fatter, less is needed, something like five pounds a day. On a milk diet, an active person would need about ten pints of mare's milk or six pints of cow's milk a day; there is a good deal of fat and carbohydrate, as well as protein, in milk. Since flesh foods are perishable, habitual meat eaters get used to eating vast meals when fresh meat is available after a kill, and then starving until the next one; to the examples given on page 81 we might add that a Patagonian, after days with nothing to eat, will consume 15 to 20 pounds of guanaco, and an Eskimo will easily eat 14 pounds of raw salmon.

Tropical peasants who live primarily on starchy foods such as rice or yams or bananas get their energy requirements almost entirely from carbohydrates, but living in warmer climates and leading less active lives than the Eskimo or the Canadian boatman they need fewer total calories; even taking into account their lower requirements, however, the diet of a poor rice-eating peasant of Bengal or Madras seems insufficient in total amount, consisting as it does of from 14 to 26 ounces of rice a day, with about another half-pound of millet, pulse or starchy vegetables. This contrast in the amounts of food eaten is well expressed by Russell Smith, who calculates that whereas an ox represents in food value about 150 days' rations for a Canadian, it represents ten years' rations for an Indian ryot.

Between these two extremes of an all-meat and an almost all carbohydrate diet lie the mixed diets that most of us are used to, containing food of all three types. A well-balanced diet, according to one estimate, should contain about 10 per cent or 250 calories of protein, 25 per cent or 625 calories of fat, and 65 per cent or 1,625 calories of carbohydrate, to make up a total of 2,500 calories. This is a pre-war estimate, as will be realised when I add that this amount of protein is equivalent to a daily intake of ten ounces of lean meat, or nine ounces of cheese, or nine eggs.

A diet which is short of calories is only too common all over

the world: many peoples live permanently on the very verge of starvation. This is true in particular of primitive peoples living in a very difficult environment, such as the margins of deserts, the Arctic regions, or the wet, sunless beech forests of the extreme south of Chile. Most hunting and collecting peoples live in this state; their supply of food is always precarious, and, because numbers of game animals fluctuate from year to year, in some years many of the hunters and their families die of famine because there is so little game to be had. Other men who live always in fear of starvation are peasant farmers of many parts of the world, but particularly of the overcrowded parts such as much of India and China, where there are too many people to be fed properly from the land, and they are too poor to buy more food because on their tiny holdings there is no room to grow anything extra to sell in exchange for food from elsewhere.

We have here two very different examples to illustrate the relation of man to his natural environment, and how that relation is affected by the stage of culture to which he has attained. The Bushmen, skilled hunters who formerly ranged over most of southern Africa, have been forced by the Bantu and later by the white men into the parched shadeless scrub lands of the Kalahari desert whither the game has retreated, and in that arid and uninviting land years of plentiful food are all too rare; the rainfall, on which the pasture for the game depends, is scanty and very irregular; water is scarce and difficult to find, and apt to dry up just when it is most needed; the Bushman literally never knows where his next meal is coming from, nor whether it will come today, tomorrow or never. Other hunting peoples of the present day lead equally austere and precarious lives; as a result of the mysterious cycles of wild life in Labrador and much of the sub-Arctic bad years for caribou or seal recur with distressing regularity and in the worst of these whole communities, and up to two-thirds of the whole population of Nascopie Indians may die of starvation. In these conditions, there is seldom enough to eat except on rare occasions. Here we see in

action the natural checks on the increase in numbers of men, by a restriction of the numbers of the species forming the base of their food pyramid. In China, or India, on the other hand, the pyramid has become top-heavy in spite of all efforts to broaden its base by growing more and more food : deliberate restriction of numbers by such means as infanticide is only practised among the very poorest of the peasantry, and large families are often sought after for religious and social reasons, so that the population has grown beyond all possibility of intelligent control. The soil is fairly good, summer temperatures high, and rain heavy and reasonably reliable, so that, if carefully tended, crops grow fast and bear well ; the population, which steadily swells through a series of good years, is too large to feed itself in years of poor harvest, and, unless food can be brought in from elsewhere and distributed, famine tragically and brutally cuts down the numbers of men that must be fed from the soil. Man here, in fact, has reached the upper limit of increase made possible by increasing the amount of food that he grows. At the cost of ceaseless watchfulness and heart-breaking toil he squeezes from the soil every seed and green leaf that it can be made to bear in the good years, only to have his children, for whom he worked, starved to death or debilitated for life when the wheel inexorably turns and the lean years succeed the fat ones.

The Monsoon lands of Asia are obviously overcrowded in many parts, and their recurrent famines are evidence of this fact. It is not perhaps so obvious that many thinly peopled parts of the world, such as the Sudan, much of Australia, and the Dust Bowl of the United States, are also overcrowded, but here periodic famines are just as common as in Asia. They are not always spectacular disasters in which thousands of people die ; they affect fewer people directly, and so their worst results are more easily avoided, but their causes are in reality very much the same as those of the great Asiatic famines. Their root cause lies partly in physical geography, in an irregular, unpredictable and scanty rainfall, with recurrent cycles of drier and wetter years. It lies also in human geography, in a badly adjusted

relationship between the physical environment and the use man has made of it. It is a very difficult environment to use well, especially for agriculture; controlled grazing is probably a better way of using the land than is arable farming. Here, for instance, are the amounts of rainfall, measured in inches, that fell in nine successive years from 1913 to 1921, at Maiduguri in Northern Nigeria, south-west of Lake Chad :—

1913	1914	1915	1916	1917	1918	1919	1920	1921
20·0	11·2	24·9	34·2	21·5	35·1	16·6	15·0	28·4 ins.

Here the year's rain in 1914 was less than the amount of rain that fell in a single month in 1916 and 1918. Rains in a normal year last from April to October: in 1920 they ended in July, and in 1914 did not begin until June. This is fairly typical of the rainfall in these dry grasslands; towards the deserts the rain gets more and more erratic as it gets less, while as it increases in amount away from the deserts it also becomes more dependable.

These areas are often good stock country, whether the stock be wild or tame. The Plains Indians of North America adapted their way of life very well to the geography of the Great Plains, living by hunting the bison that roamed the prairies in almost incredible numbers. In the Old World, after man had learnt to domesticate animals, which he never did in most of the New World, nomadic pastoral folk such as the Jewish Patriarchs, the Kirghiz of Central Asia or the Arabian Beduin roamed the grasslands along with their herds of domesticated cattle, horses, sheep or camels; seldom over-fed, they were yet as a rule fairly free from bad famines except in cycles of dry years such as those which drove Jacob's sons to Egypt to buy corn. The Bible story also shows clearly the reliance placed by the desert and steppe pastors on the oases, for food for themselves and their flocks in years of drought and so of scanty pasture. In the oases the water supply is generally reliable, coming either from underground springs, as in the big oases of Biskra and Tougourt to the south of the Atlas Mountains, or from rivers like the Nile, rising in distant mountains where drought is unknown, or from smaller streams fed by rain or snow on mountains near

at hand, as in many of the oases of Central Asia. Crops can be grown by irrigation in the oases, and so are unlikely to fail completely.

But if people try to use the grassland away from the oases for cultivation, they have to rely on the erratic local rainfall alone. In a cycle of wetter years, as for instance from 1915 to 1918 at Maiduguri, the rain is abundant; the grassland soils are often very fertile, and the crops do well. Then comes a cycle of drier years, with perhaps less than half the rain of the wetter ones; the sheep or cattle, which have increased in numbers during the wet years, get thinner and weaker as the pasture fails and the water dries up, and finally die from starvation or drought; the crops shrivel and fail, and hungry villagers take to marauding forays to raid the cattle and stored grain of others more fortunately placed; finally the seed corn is eaten, the starving people desperately strive to keep alive on bark, grubs and earth, and in the end, in a bad famine, half or two thirds of the total population may die of starvation. Even where man has not taken to ploughing the grasslands, but stocks them instead with beef cattle or sheep to be sold to feed the industrial cities, the same discouraging rhythm occurs; during the good years an ever-increasing livestock population, followed by drought, failing pasture, drying streams, and then the death of vast numbers of animals if they cannot be shipped to better country or have food and water brought to them in time.

This overstocking brings other and even worse disasters in its train, as does ploughing the sod of the natural grasslands; we shall consider the other effects, those upon the soils and the ground water, in Chapter IX. Here we are only concerned to note the way in which the geographical environment, through the natural vegetation and so the food supply, exerts a strong control on the numbers of animals and so of men that can live in an area. The population of these dry natural grasslands is nowhere high, except in oases; in two and a half million square miles of the Sudan the population is only about twenty-seven million, or roughly eleven to the square mile; as we have seen,

the density of hunting peoples, relying only on natural foods, is less than one to the square mile. The richest parts of India and China, with their hot rainy climates and fertile river-mud soils, support in places from 600 to over 1,000 people to the square mile. The difference between a density of eleven people or fewer, and one of over a thousand people to the square mile, is a measure of the differences in physical environment between the grasslands and the monsoon lands, between the scanty, sporadic summer rains of the Sudan and Australia, and the steady downpours, month after month, of the Asiatic Monsoon.

But the Monsoon environment is very well suited to farming; had man relied only on hunting, even there the population would scarcely have exceeded one to the square mile. We must always remember that the physical environment alone does not determine the numbers of people that can be supported by an area; the stage of culture reached by the people is of enormous importance also. You could draw a map showing the parts of the world where famine was likely, but you would need to state as well whether the map applied to hunters or to farmers, because the ways in which the two use their environment are so completely different. For one thing, hunters need water only for themselves to drink, or perhaps to cook their food in; pastoral peoples need it also for their cattle to drink, but farmers need very much more of it than either of the others, because their crops have to have so much as well as themselves. Hunters, therefore, probably are less affected by drought than either pastors or farmers. However, nowadays almost all the people in the world are either farmers themselves or rely on the food grown by farmers, and we shall not have much more to say about hunting peoples after this chapter.

Food, then, considered only from the point of view of quantity as we have done here, is chiefly important in man's distribution and activities by reason of the controlling effect it exercises on the numbers of men that may live in a given way in a given environment. If the numbers of the men exceed the limits set by the physical factors, famine comes to adjust the balance

between man and nature. In its train some pestilence, civil disturbances or wars, and a long, heart-breaking tale of lifelong misery, stunted bodies and shortened lives resulting from partial starvation. The trail of desolation that follows a bad famine may stretch for years, as the ill-health it leaves behind shadows the lives of the survivors.

Local famines are a symptom of poor adjustment of man's numbers and way of life to his local environment. We westerns think that nowadays we have conquered famine, at least in most modern commercial countries, but we do it only by drawing our food from somewhere else. In view of the increasing numbers of men all over the world, that is a process that cannot go on indefinitely. We have not really solved the famine problem, we have only shelved it. If we let our numbers increase as they are doing at present, when the problem does again present itself for solution in the densely populated urbanised countries of Western Europe and North America, it will be an infinitely greater and more difficult problem to tackle than it has ever been hitherto, even in India or China, because it will only reappear when there are no more lands left from which to draw extra supplies of food. Unless mankind as a whole sets seriously about finding a possible solution to the problem before it arises in concrete form again, by intelligently and foresightedly tackling the task of adjusting the numbers of men to the world food supply, it is difficult to see what way out will be left us from a situation of such horror that the imagination quails at any attempt to picture it. If man cannot arrive at a just balance between the numbers of his own species and those of the subservient plant and animal species that he needs to keep him alive, he is likely to destroy civilisation by famine just as certainly as by the atom bomb.

CHAPTER VII

MAN AND HIS FOOD: AGRICULTURAL AND DIETETIC PATTERNS

WE do not know how men first learnt to grow crops. It is an invention which has often been credited to the women of the family, but there is no evidence one way or the other. Primitive peoples today are wonderfully wise and observant in all things concerning the wild animals and plants they use for food, and it would not be very hard for them to learn in the earliest days that the seeds they collected, if left on the ground or allowed to get wet, grew up into new plants of the same kind. The next stage, that of sowing seeds deliberately in a clear patch of ground, is more difficult because it needs foresight, which is rarer in primitive peoples than the faculty of observation, but that step once taken agriculture had begun.

We know rather more precisely where man first learnt to grow his own crops. In different parts of the world the staple bread-stuff differs; it is wheat in Western Europe and the Mediterranean; rye in Central and Eastern Europe; barley in the Near East; rice in the Far East; maize in primitive America; millet in some parts of the Tropics, and in other parts of the Tropics starchy vegetables and fruits such as manioc or cassava, yams, sweet potatoes, bananas and bread-fruit. The ancestors of these different crop plants, so far as we know, originally grew wild in several widely separated places. The different groups of early men that first began to cultivate them deliberately instead of just collecting them must, it seems, have had the same brilliant idea separately in separate places. So we owe our own chief bread-stuff, wheat, whose ancestors grew wild in north-east Africa and south-west Asia, to the early dwellers in the big river oases of Egypt, Mesopotamia and probably the Indus valley: along with wheat of various kinds these people

also grew barley and flax, and the Indus people had dates. Our secondary bread-stuff, the potato, came to us some thousands of years later than wheat, not until after the discovery of America, where it was a staple food of the Indians of the highlands. Rice was probably first brought under cultivation in the Far East, though there is some evidence that it too was grown in the Indus Valley. Cultivated maize, of which no direct ancestor is known, most probably originated in America. The various starchy tubers and fruits of the tropical peasant may first have been cultivated in Tropical Africa, or possibly the idea of tending them originated at many different places in the tropics at different times. As some of them are tubers like our potato, new plants might spring up accidentally, as they do from the eyes of a potato, from injured parts cut out, or from bits of peeled rind thrown aside by some early housewife when preparing the family meal from wild tubers, and so the idea of cultivating them would easily follow. One of the fascinating problems connected with these plants is how man first found out that the intensely poisonous ones, such as the commoner kind of manioc, which is the source of our innocuous tapioca, could make good food if suitably prepared. Perhaps he first used them to extract poison for killing game or fish, and having extracted the poison discovered that the starchy residue was good to eat.

Wherever and however agriculture began, it did so very long ago. In Egypt and the Near East, where finds can be dated with very fair accuracy, the first cereals were in cultivation before 5000 B.C. Agriculture in America possibly began a good deal later than this, but dating here is more uncertain than in the Old World. Maize has probably been grown by men for a very long time because it is extremely variable, as long-cultivated plants often are; there are hundreds of varieties of maize known, particularly among the Indian peasant farmers in the highlands of Central America.

It was the happily-placed dwellers in the river valleys that thread the Old World deserts who made the first great progress in the arts of agriculture, and first tamed many of the ancestors

of the domestic animals we use today. These river valleys, when the first settlers came to them, were much less attractive to farmers than they are now, being swampy, forested and infested by large animals such as wild pigs, elephants, hippos and crocodiles. The desert on either side, however, was less completely arid than it is now, and herds of game thrived on its thin pastures. Slowly, the settlers drove out the animals and reclaimed the swamps in the valley floors; the climate was getting drier, too, as the last ice-sheets of the Glacial Period far away in the north were melting slowly back, and so cultivation spread in the oases and men increased. In Egypt above the delta there was no rain, but the White Nile was fed all the year long by the equatorial rains on the forests around Lake Victoria, and yearly, as the water of the summer rains on the Abyssinian highlands swept down the Blue Nile, the river of Egypt rose in the autumn to inundate its valley in the desert with muddy water, spreading on the fields the fine silt brought from the far lands at its source. Behind the receding water the peasants sowed their seed on the mud, and the drenched ground remained wet enough through the winter to bring the crop to maturity without further watering. In spring the grain ripened in the drying soil and the increasing heat, and was harvested before the scorching summer drought set in. Year by year the Nile waters spread new silt on the land, so that the Egyptians had not to attack the problem that defeated most early agriculturists and many later ones, that of declining soil fertility; they had no need to apply manures to maintain the yield of their crops. When the Nile flood was not high enough, they did suffer from periodic famines, as we know from the Bible, but for the most part they were well-fed folk, and in the security and prosperity of their favoured land, protected by the desert from encroachment by envious neighbours, they built up a magnificent and stable civilisation that lasted for thousands of years.

It is not surprising that they were such energetic and accomplished people when we consider the sort of food they lived on. Here is the menu of a children's school in Egypt during the

brilliant 18th Dynasty, about 1500 B.C. "The children were great and small, sixty . . . they all consumed 120 ephas of dhurra (a kind of millet), the milk of three cows, fifty-two goats, nine she-asses, a tin of balsam and two jars of oil." In the succeeding 19th Dynasty, "the king's messengers had good bread, ox-flesh, wine, sweet oil, fat, honey, figs, fish and vegetables every day," as we know from an inscription. Soldiers had a daily ration of four pounds of coarse bread, with onions, garlic, cucumbers, radishes and turnips eaten raw, and lentils, beans, artichokes, asparagus, beetroot and cabbage cooked. The fruits of ancient Egypt included melons, grapes, figs, dates, pomegranates, carobs, olives, apricots and various seeds. It is interesting to notice, from the evidence of skeletons found in graves, that the poorer people who lived on the same sort of coarse food as the soldiers had excellent teeth, while the aristocrats, living on softer and more delicate foods, had just as many tooth troubles as we have today. But if these diets are representative of the diet of the people as a whole it is no wonder that they were vigorous.

The dwellers by the Euphrates and Tigris were not so favoured in their physical environment as the dwellers by the Nile. The Nile flows from south to north, from the tropics to the temperate zones, and since its flood is fed by the summer rains of the tropics it rises in Egypt in autumn, and the weather during the succeeding winter is not hot enough to dry out the land completely all at once. Also, in its thousands of miles from source to sea, it passes through a colossal swamp, the Sudd, filled with papyrus reeds and other aquatic plants, and then over a number of cataracts. In the Sudd and in the pools above the cataracts the coarser silt is dropped, leaving only the finest fertile mud to spread upon the fields of Egypt. The Euphrates and Tigris, on the other hand, flow from north to south, and their floods are fed by the melting snows on the highlands of Asia Minor, and so come down in early summer. The flooded land dries out quickly during the oven heat of the Mesopotamian summer that follows the floods, so that to grow crops at all water must be stored in canals and reservoirs, which are difficult to construct

in that flat plain of river mud and silt, where there are neither good sites for dams nor rock to use as foundations. There are no swamps and few cataracts in the higher reaches of the rivers to act as settling tanks for the coarser silt, which thus sweeps down unchecked to the lowlands and makes the task of keeping the reservoirs and canals in good condition extremely arduous. This silt is too coarse to be immediately fertile, like the fine Nile mud. Lastly, Egypt, surrounded by deserts on all sides but the north, lay on the edge of the civilised world in the days of her glory, whereas Mesopotamia lay in the very centre, at a great cross-roads of traffic where the route from the Mediterranean to the Persian Gulf and India crossed that from the highlands of Persia and Anatolia to Egypt. All through their turbulent history the successive empires that flourished in Mesopotamia were ravaged by wars, and in the upheavals caused by the wars the canals which brought the life-blood of the country fell easily into decay. In Egypt, nature has helped man all through his history; in Mesopotamia she has been too strong for him. Today, Mesopotamia is a parched, waterless country supporting a small and indigent population, drawing its wealth not from the soil but from its mineral oil, whereas the Nile valley is still, as it has been throughout its long history, one of the most fertile and the most densely peopled agricultural regions in the world.

Northward from Egypt and probably inspired by her example, a different type of farming early grew up around the shores of the Mediterranean Sea. It was suited to the peculiar Mediterranean climate, which has the intensely dry, hot summers of the deserts to the south and warm, rainy winters like those of north-west Europe, but sunnier. The wild vegetation, in the few places where it has not been destroyed, is a woodland of evergreen trees, growing very slowly and having small hard leaves. Mediterranean trees can never grow very fast; in summer, when it is hot enough to do so, it is too dry; in winter, when it is wet enough, it is too cool. So the trees grow slowly, toughly, to a great age, making very hard wood; since they are evergreen they need not waste time putting out fresh young

leaves in the rare spells when it chances to be warm and wet at the same time, but can grow away at once and make good use of any favourable weather. The typical tree of the Mediterranean is the olive, which has small leathery silver-backed leaves and dark oily fruits. The original Mediterranean forest probably had many olive trees, and pines and cedars of various species, with chestnuts, cork oaks and evergreen oaks on the higher ground; it has nearly all been cleared long ago for cultivation, and in the wilder country it is kept down by grazing goats and sheep. Its place is taken by a shrubby woodland or heath, the "maquis" of southern France, with, instead of evergreen trees, low bushy scented evergreens, lavender, cistus, heaths and rosemary.

In this climate cereals can grow only in winter, when there is rain. Wheat sown in autumn grows well through the wet sunny winter and ripens off as the weather gets hot in spring, to be harvested at the beginning of the summer drought. Wheat is the main bread-stuff of the Mediterranean basin; the climate particularly well suits the hard wheats which make paste better than they make bread; hence the Italian's fondness for macaroni. In the blazing summer all grass shrivels and there is no pasture for cattle, though goats can make a living in the evergreen scrub, so animal fats are scarce, but olives provide oil instead; the Mediterranean peoples use olive oil much for cooking and spread it on their bread as we do butter. Drinking water is scarce and bad in summer, and so is milk, so the Mediterranean peasant drinks wine, because the deep-rooted vines, like the olive-trees, can draw up from the subsoil the water that collects there during the winter rains.

The staples of Mediterranean farming, then, are wheat, grown in winter by rain, and olives and vines which grow and ripen in the fiery summer, fed by water from deep underground. The Mediterranean peoples farm on a system which has evolved through long ages to suit a peculiar and difficult climate. It is not a system perfectly adapted to the whole environment, but it has at least managed to survive without much change for

several thousand years. As in many other parts of the world, its present troubles are largely due to the great recent increase in the numbers of people that have to be fed from the soil ; this has led to overmuch felling of the natural woodlands of olives, oaks and chestnuts, and too much replacement of trees by quicker-yielding crops, which let slip through their roots the thin soils that cover the burning Mediterranean limestones : this region suffers badly from soil erosion in consequence. The goats are another menace to the stability of the soil, since they destroy the wild plants that might help to anchor it and they prevent new seedlings from establishing themselves.

The traditional Mediterranean diet is based on wheat, made into bread or various pastes, olive oil, and wine. Chestnuts, another tree crop, are used for human food, and pigs, fed on the acorns from the oak woods on the hills of Spain, are turned into excellent hams. Goats'-flesh and fish—sardines, anchovies and others—add protein and flavour, and fruits and vegetables of all sorts, which grow easily in this sub-tropical climate, add further variety and substance to this excellent diet, which sustained the Ancient Greeks and the Romans in the days of their greatest glory.

The idea of agriculture spread northwards and westwards from the Mediterranean into the barbarous forest-covered lands of northern Europe. But as the climate altered towards the cool, damp north-west and north, crop after crop of the Mediterranean farmer was perforce left behind in the more genial south, and the staples of north-west Europe in early days were far less varied than those of the south. In compensation, pasture was richer in the cooler wetter climate, the forests abounded in game and the seas and rivers in fish, so that the outlandish dwellers in the savage north had probably a good deal more protein in their food to help them keep warm and energetic among their swamps and fogs.

In Northern Europe our earliest evidence of agriculture comes from peat-beds that were forming as the ice-sheets of the great Ice Age were finally shrinking back into their last fastnesses in

Norway and the Alps. In these peats pollen grains are preserved which blew from the trees of the surrounding forests and fell as a fine rain of pollen on to the bogs where the peat was forming. The grains can be identified and counted, and the proportions between the numbers of grains of different kinds allows us to build up a picture of what the surrounding vegetation must have been like. We have to imagine, about 5000 B.C., a Europe covered with thick primeval oak-forest everywhere but on the hilltops and in swampy river-beds, or bogs, where the ground was unsuited to trees. We must picture a dense, dark woodland, leafless in winter, perhaps carpeted with flowers in spring, very like the deep forests of the eastern seaboard of North America in the days of the early settlers, described in Fennimore Cooper's stories. A less promising country for farming with primitive tools could scarcely be imagined. Yet with their feeble tools our ancestors felled the great oaks and burnt them, to get patches of clearer ground in which to grow their crops. The story is told clearly in the peat. Suddenly, after layer on layer of peat where there is little but the pollen of the great forest trees and the spores of ferns, comes a layer blackened with charcoal dust, and suddenly the tree pollens diminish in numbers; instead come in the pollens of plants of open country and clearings, grasses and herbs; more revealing still, there come in the big round pollen grains of cultivated cereals, and with them the pollens of our all-too-familiar weeds, plantains, docks and the rest, that have dogged man's footsteps since the days of Adam.

Then, it appears, these early farmers let their hard-won patch grow up again to scrub and weeds and small shrubs, and slowly the forest swallowed it; the cultivated plant and weed pollens disappear, and first hazel and scrubby bushes, later the great forest trees, come back into their kingdom; our farmer has moved on to make himself a new clearing in virgin soil elsewhere, as shifting cultivators in the jungles of Assam do to this day. He had not yet learnt how to keep the fertility in the soil he used for his crops, and had to give his plot back to nature to

do it for him. The first settlers in North America, many centuries later, did exactly the same thing, but there were far more of them, and they made a much more thorough job of clearing the forest in the first place, so that it was unable to re-establish itself properly. The consequences, as we shall see in Chapter IX, were often disastrous, and we are still feeling them now.

In Denmark a beautiful piece of work has been done by Georg F. L. Sarauw and Knud Jessen to discover what crops some of these early European farmers grew. The farmers made crude pottery, working the clay for it on the patch of hard clear ground outside their huts, where also they threshed and ground their grain. So it happens that some of the pots in the making caught up a grain or two underneath in the wet clay, and when the pot was fired the grain was burnt out and left a hole in the clay. From the shape of the hole left, the shape of the original grain can often be recovered and the grain identified. In this way the investigators found that the early Danish farmers in the New Stone Age grew three kinds of wheat and two kinds of barley, while apple pips and the seeds of a polygonum, allied to buckwheat, were also found, but these may have been from wild plants. If the proportions in which grains are found represent roughly the proportions in which the different cereals were grown, in the very early days the farmers grew six or seven times as much wheat as they did barley. Later, by 800–400 B.C., they were growing also a kind of millet, and oats : each of these makes up only two per cent of the total grain impressions found : they also grew peas, beans, and the polygonum mentioned above. But by this time the proportions of barley and wheat are reversed ; they grew six or seven times as much barley as wheat. Rye first appears at about the beginning of our era. The oats and rye, later grown as crops, were originally weeds in the wheat and barley fields. It is interesting to see how the warmth-loving wheat of the early days was replaced after 800 B.C. by hardier barley, oats and rye which can stand cooler conditions, for we know from other sources that the climate of northern Europe was deteriorating at that time.

The diet of these early farmers was probably much more varied than their limited list of crops might lead us to suspect. Their predecessors, the hunters and food-gatherers of the Mullerup culture, a Mesolithic folk of about 6000 B.C., collected hazel nuts, seeds of the yellow water-lily, berries such as currants, raspberries, strawberries, blackberries and bilberries, and sloes, hips, haws, rowan berries and crab apples: they also hunted red deer, roe deer, elk, urus, wild boar, beaver, badger, pine marten, wild cat, fox and hedgehog, and large birds such as ducks, storks, cormorants and coots. The Neolithic farmers may have used all these wild foods, particularly in bad seasons, but they had their own domestic animals as well, including cattle, sheep, pigs and goats, and they ate meat and presumably also drank milk, though this is not easy to prove. They certainly brewed beer from barley and wheat and flavoured it with berries, and they also made mead from honey. It is thought that they may have made cheese. By the Bronze Age they had horses, but cats and poultry did not arrive until Roman times.

Part of the long subsequent history of agriculture in northern and western Europe will be found in the book in this Series on Historical Geography. Through centuries of experiment, the European farmers built up on their cold, moist soils what is probably the best system of farming man has yet evolved, because it not only provides the folk who use it with a superb mixed diet containing plenty of animal foods such as milk and meat, but it should also improve rather than impoverish the soil. So it comes about that Western Europe, and the Far East which has also evolved a system of truly conservative farming, are the only parts of the world that feed very large numbers of men and yet are still relatively free from soil erosion (see Chapter IX).

The climate of Western Europe is suited to mixed farming, with animals as well as crops, feed-stuffs such as hay, oats and turnips as well as foodstuffs such as wheat, potatoes and vegetables. Details vary enormously with local conditions, but in general, European farming of the best kind is based on rotation of crops, so that the same crop plant does not occupy the same

ground for more than one season; food crops, taken off the land, regularly give place to feed crops, which are either eaten off on the ground by stock, who return the residue in their dung, or fed to cattle in byres, where the manure is collected to be later spread upon the fields. Each crop in the rotation makes different demands upon the soil, which is never so severely impoverished by any one crop as to be unable to recover completely under other crops in the rotation before the exhausting one returns again.

It is impossible in a few paragraphs to give a good idea of the variety of practice in European farming, so I shall mention only one or two systems that have proved their worth. The first of these is the traditional English "Norfolk four-course shift," which for nearly two hundred years held its own on many of the light lands of Great Britain. This is a four-year rotation of (1) Roots, (2) Barley, (3) Seeds, (4) Wheat. The roots are folded by sheep which manure the ground in readiness for the barley, and during the summer eat down the seeded grasses on the land that is to be sown to wheat. The roots are also fed to cattle which tread down the straw from the cereal crops into farmyard manure. This system produced wheat, high quality malting barley, mutton, lamb, wool and beef. Nowadays, with labour at a premium, the numbers of animals have declined, and sugar beets tend to take the place of the roots formerly folded to sheep; sometimes another year or more of barley or oats is added to the rotation, to give more of the saleable crops, but the proportion of animals becomes steadily reduced by this practice and the farmyard manure must be replaced by artificials and green manures, as some hold to the detriment of the soil. A suggested improvement is to include in the rotation more temporary grass pastures or leys; these are grazed by stock which spread their dung evenly over the land. The ploughed-in sod is the only manure that the land is held to need when this ley system is used in its entirety, as recommended by R. H. Elliott in his Clifton Park system. On heavy land, for instance, a good rotation might be a four-year grass ley, followed in successive years by

wheat, beans, wheat, and oats or barley, reverting to grass again in the ninth year.

Variations of this Norfolk rotation are found on the continent, in Denmark and in parts of Germany and France; in the north of France and the Paris basin the usual rotation is a three-course or six-course one: wheat, oats, lucerne; wheat, oats, roots. France has more than half her cereal acreage in wheat. In Belgium agriculture is very intensive, with a very large area devoted to root crops, such as potatoes, which are eaten by the peasants themselves; this reflects the lower standard of living of the Belgian peasant as compared with the English farmer. In Holland and Denmark the rotation is devised more for the sake of the cattle than with a view to cash cropping; four-fifths of the Dutch rye and oats, and half the barley, is fed to livestock; of the quarter of the total arable acreage devoted to roots, however, the greater part is under sugar beet and potatoes for human food. But everywhere the farming is solidly based on the physical geography; this mixed husbandry of animals, grass and fodder crops and some cereals and root crops suits to perfection the moist mild climate of north-west Europe and the soils we have inherited from the forests our ancestors cleared. The English climate is not a very good one for wheat: we have not had a really good wheat climate for some 2,500 years at least; but it suits oats, rye and barley very well and grows excellent grass in spring and summer for cattle. Turnips and other root crops, which made slow but steady headway into English farming after A.D. 1700, can be used to carry livestock through the winter when the grass is short and growing very slowly, and clover leys and other leguminous crops not only make good fodder but enrich the soil with nitrogen.

The diet based on this farming is our traditional English diet of bread, beef and beer: bread from wheat grown on the best land; beef—with other meats such as mutton, lamb and pork—raised on grass and roots; beer brewed from the barley in the standard rotation. This excellent solid foundation, which carried our ancestors through some of the most trying periods

of our history, bears in later times a rather more flimsy superstructure consisting of potatoes, cheese, milk and other dairy products, fish, and vegetables and fruits of a large number of kinds. Honey, used for sweetening in earlier days, has been almost entirely superseded by sugar. Our country has always done well for fish, though it is doubtful whether the Arctic cod, stored in ice chambers for weeks before it appears in the shops, is a really efficient substitute for the fresh salmon that we have driven away from nearly all our rivers where they used formerly to abound. The latest almost universal additions to our staple diet seem to be that curious synthetic product euphemistically known as "ice-cream," sweets, and fish and chips.

The cultivation of rice probably originated in South-eastern Asia, perhaps in the swampy river-flats of the Ganges and Brahmaputra valleys. Rice may have been grown very early in South China; however, the staple cereal of the earliest Neolithic peasantry of North China was not rice but millet. Rice is the staple foodstuff of about one-third of the human race, living in the densely-populated monsoon lands of Asia; nine-tenths of the world's crop of rice comes from China, Japan, India, Burma, Indo-China, the Philippines and the East Indies. Rice is said to feed at least four hundred million people in these countries—most estimates put the figure higher, at about seven hundred million. It is the cereal of the rainy Tropics for the most part, because it needs not only very high temperatures, over 80° F. and preferably higher, but also plenty of water round its roots, being by origin a swamp plant which must stand in water throughout its growing season. This season varies in length with different varieties: some need eight or nine months to complete their growth and ripen, but there are even two-and-a-half to three-month rices to be found in places.

Rice is a remarkable cereal, and its peculiar method of cultivation automatically solves many of the worst problems confronting the farmer in the Tropics: weeds, the difficulty of ploughing soils baked hard by a tropical sun, soil erosion, and loss of soil fertility. When it is grown by the traditional

methods it requires an enormous labour force, but it also yields heavily and will support a very dense population. To grow rice, the land must be made dead level so that the water can stand on it; this is accomplished by terracing in hilly country. In some places such as the Philippines and Japan rice terraces run far up the hillsides and on steep slopes each may be hardly larger in area than a tablecloth. Elaborate works are necessary so that the water does not stagnate but moves very slowly from one field to the next lower in the series; from the lowest of all it often has to be pumped out by hand to prevent flooding. Few weeds can grow in the water; it can be led on to the field by irrigation before the rice is ready to plant, and the soil thus softened can be worked easily even with simple tools, or with a plough drawn by a water-buffalo. The water moves so slowly that it does not erode the fields; rain is caught by the terrace rims and does not rush down the hillsides to wash them away; the silt in irrigation water drawn from rivers has time to settle on the fields and so restore their fertility. In China and Japan manure is added as well: all possible wild vegetation from the terrace banks, weeds and mud dredged from the rivers, animal dung and human night soil are carefully collected and made into compost to spread on the fields. In India, where the cow is sacred and human ordure is ceremonially untouchable to many Hindus, this is not done: much cow-dung, instead of being returned to the soil, is burnt as fuel in a country tragically short of trees, and the fertility of much of the land is desperately low.

The swarming populations who use rice as their main foodstuff are not, by our standards, at all well fed. Rice will not bake into bread, but it makes an excellent light digestible meal if the grains are boiled so that they remain separate and do not congeal into a gluey mass. It is not rich in protein, but properly prepared and cooked it has enough protein for tropical peoples, who do not want a heating food. Generally, it is eaten plain, with relishes, often very fiery to our palates, made from all sorts of vegetables and fruits, such as chili peppers, turmeric, ginger, cardamoms, coconut and dozens more, and also from some

animal foods such as a peculiar kind of shrimp, which when half-decayed is made into a sauce much appreciated with boiled rice in Burma and Indo-China.

The poor Indian peasant eats an astonishing amount of rice, and very little else. The table below shows the daily diet in ounces of rural families in three Indian lowland rice-eating areas, with Kashmir for comparison.

	Rice	*Millets*	*Pulses*	*Leafy veg.*	*Non-leafy veg.*	*Veg. fats and oils*	*Fish, eggs and meat*	*Milk*
Madras	15·0	5·0	1·3	0·3	1·5	0·5	Negligible	None
Bengal	25·0	None	0·4	0·2	7·0	0·3	0·7	None
Central Provinces	26·0	None	1·1	1·5	3·0	0·2	Negligible	None
Kashmire	26·0	None	0·6	5·2	2·0	0·9	0·2	2·2

Condiments and sugar in small quantities.

In three of these areas a peasant will eat regularly over one-and a-half pounds of rice a day, and much of the rest of his food is starchy vegetables, or in Madras millet, a good and nourishing, though despised, foodstuff. The Kashmiri drinks in addition about a pint of milk a week, and none of them eat any appreciable amount of animal foods. For comparison, my cookery book gives, as the quantity of rice needed for the English version of curry, four ounces of rice for three people, or 1·3 ounces each, one-twentieth of the Kashmiri's daily rice consumption, while a pre-war rice pudding took only 1½ ounces of rice for four or five people along with 1½ pints of milk—three days' ration of milk for the Kashmiri per person, but only about one-seventieth of his daily intake of rice. It is said that habitual rice-eaters have stomachs permanently swollen to cope with this extremely bulky diet.

The cereal maize is a gift of the New World, where it was first cultivated. Its wild ancestors are unknown, but it may have originated in the foothills of the equatorial Andes, or possibly, but this is highly controversial, in Assam. It is an extraordinarily variable plant; besides the familiar dent corns and flint corns, there are maizes of all colours and kinds with

all sorts of unexpected uses, from the glutinous maize used as a raw material for plastics because of the peculiar structure of its molecules to a dark cherry-red maize which is used as a dyestuff, and even a blue corn, used to make pastel-coloured pancakes as thin as tissue paper.

Maize, like rice, does not make a good bread; corn bread, to be palatable, must be eaten hot from the oven, and we can trace the fondness of Americans for hot fresh bread to this characteristic of maize. The Indians parch maize, when the grains break up more easily, and may eat it just like that, without further preparation; the daily ration of a labourer in Bolivia or Peru is a small bag of parched maize. Otherwise they grind it into flour and make it into thin flat cakes, eaten, like the Asiatic's rice, with various fiery condiments. To accompany this meal the native Americans had only game or fish, and a few vegetables such as pumpkins and squashes, tomatoes, potatoes and beans. They never domesticated any horned cattle, so that their only available meat was either game, or derived from small domestic pets like turkeys and guinea-pigs. Meat of any kind was probably rather rare in the diet of American Indians in the highlands, and they had no milk products of any kind until the Europeans introduced cattle.

Maize is an easy crop to grow with simple tools. The early European settlers in North America learnt how to grow it from the woodland Indians, and it stood them in very good stead, for it is an ideal frontiersman's crop, needing no laborious clearing of a whole field as wheat does; the maize can be sown straight away among the burnt stumps of the first clearings.

The staple food of the frontiersman was meat—game in the early days, later pork from pigs left to rummage wild in the woods, or fed on corn like their owners. The corn was eaten as hot "biscuits," or what we should call hot maize breads, or as "grits and gravy," with molasses and black coffee. Even today the small farmer in the South has coffee and hot corn biscuits for breakfast, with fat pork or bacon, eggs, some milk, cereals, butter and molasses, and for dinner corn-bread and

pork boiled with dried beans, cow peas, potatoes and greens. Supper is a reproduction of breakfast, with hot breads, fried meats, and eggs to supplement left-over cold vegetables. Between meals the children eat cold sweet potatoes, corn-bread and syrup, or bread and fried meat, or they chew sugar-cane. The basis of this diet is clearly maize, the frontiersman's fat maize-fed pig, and the molasses he prepared from sugar-cane or millet. Only slowly is this traditional diet giving way, under pressure of the salesmanship of fruit-canning firms and articles on health and beauty in the women's magazines, to one containing more fresh fruit, vegetables and milk, and less of the stodgy traditional foodstuffs.

Corn has one very bad drawback as a crop: if clean-tilled, as is customary in modern America, it leaves large bare spaces between the plants so that the soil is easily washed away by heavy rains. The lands where corn is grown as a single crop year after year without any proper rotation or any return to the soil, a system of husbandry that has its roots in the frontier tradition of unlimited free land, are the lands which have suffered from soil erosion more heavily than any others in the United States. We shall return to this subject in Chapter IX.

The root vegetables and starchy fruits of the Tropics are so many and so various that it is difficult to generalise usefully about them. Of the smaller plants whose underground tubers or tuberous roots are eaten, yams and sweet potatoes are ramping herbaceous climbers; cassava or manioc is a small woody shrub; taro, eddoes and dasheen (*Colocasia spp.*) are large-leaved plants related to Arum lilies, which like swampy ground and so, in hilly country, require terraces like rice; the sago of Melanesia comes from the pith in the stem of a palm which also grows in swamps; bananas are the starchy fruit of a large herb springing from a perennial root, and must be propagated by cuttings because they bear no seeds; bread-fruit and coconuts are both fruits of large trees. Of all these, the commonly-used manioc (*Manihot utilissima*) contains prussic acid in the outer layers of the root and so is intensely poisonous in its raw state, while the

various Colocasias, popular in the West Indies and in the Pacific Islands, are very acrid unless properly prepared. In flavour and consistency, yams can be compared to good mashed potato, sweet potatoes to chestnuts or parsnips, taro and its relatives to Jerusalem artichokes, bread-fruit to a rather heavy and plain suet pudding; tapioca made from manioc, sago, bananas and coconuts, have invaded the temperate zone and used to be familiar to most of us.

Often, in the wet Tropics, these crops and other fruits and vegetables are grown not in rotation, like temperate zone cereals, but all together, in a disorderly mixture mimicking the heterogeneity of the wild vegetation. Such a tropical garden might contain several large fruit trees, mangoes, oil palms, coconut palms, avocado pears or bread-fruit; smaller trees like limes, soursop, papaya, custard apple or a host of other delicious tropical fruits; edible shrubs like manioc, and smaller vegetables, with perhaps yams or sweet potatoes sprawling among them and climbing up the trees or the fence. The peasant has only to go out into his patch and dig up or pick what he needs for the moment; the crops are eaten as they ripen, for they cannot as a rule be stored for long in that moist heat with so many pests and vermin; old plants are removed and their place is at once taken by others, and so the cycle goes on. Such tropical gardens of mixed produce are common round native dwellings in the East and in the wetter parts of Africa.

Another way in which these plants are grown, where rainfall is more markedly seasonal, is by shifting agriculture. The Nagas in Assam choose a patch of wild ground, preferably virgin forest, and clear it by cutting and burning at the end of the dry season. They sow their seeds—for their principal crop is hill rice, grown from seed without irrigation—among the stumps and ashes when the first rains fall, and take a succession of crops off the patch so long as fertility lasts and perennial weeds, so common in the Tropics, do not choke the crop. When this happens a new patch is cleared and the process repeated. In West Africa, in the native food gardens about Ibadan in Southern

Nigeria, this is the agricultural pattern followed. The bush is cleared and burnt in July, when it is dry. In September, when the rains have softened the ground, the natives plant late maize, and in November yams, on " hills " made for the purpose. The yams grow and their trailing stems cover the hills. In March of the next year early maize is planted through the yams, before the late maize, planted the previous September, is ready to harvest in April. In August cotton is planted through the yams and maize; the early maize is then harvested. Beans and gourds may also be grown among the cotton. As the yams and later the cotton are used up the field, now growing largely maize, is planted to cassava (manioc) among the maize in the third year, and the cassava continues to bear during the fourth year from the original clearing, but in the fifth year the patch reverts to forest and is not used again for a long time.

Tropical garden agriculture does not leave the soil exposed to torrential rain and it imitates fairly successfully the natural forest of mixed trees, shrubs and herbs, so that it should not badly exhaust the soil nor subject it to erosion. Often, too, since the patch lies close beside its owner's hut, all the house wastes are thrown out over it as fertiliser. But shifting agriculture is a very destructive practice, destroying, if too often repeated, both the natural forest and the soil. Once cleared, the forest takes a very long time to re-establish itself, and often the clearings made for cultivation grow up, not to forest, but to a useless tangle of secondary growth full of pestilent weeds such as the Elephant grass of the Assam jungles. Since the cultivators prefer to clear virgin forest because it has richer soil and is easier to clear than this secondary growth, unchecked shifting cultivation results in widespread destruction of natural forest. The cleared soil easily washes away under the deluging tropical rain, and on slopes very destructive erosion often follows in the wake of shifting cultivation. This type of agriculture is very much of a make-shift, an early stage in the experimental process of trial and error by which man learns to adjust his methods to his physical environment.

The diets based on these tropical foodstuffs are as varied as the foodstuffs, but they have certain features in common. They are generally almost entirely vegetarian, but if game is available it may be used, and often pigs are kept. These starchy vegetables are not very interesting in themselves, and so strong flavours derived from other vegetables such as pepper or ginger or from animal foods are sometimes added to them, just as the Indian ryot makes his main dish of boiled rice more appetizing by adding to it a highly flavoured curry sauce. Bread as we know it is unknown to the more primitive peoples living on these tropical vegetables, though some of the vegetables roasted in hot ashes or well boiled may have a floury consistency rather like that of mashed potato, and others by special preparation—manioc or cassava, for instance—yield a flour which can be baked into thin hard cakes though it will not rise into a spongy loaf. The food of many of these tropical peoples would seem to us dreadfully monotonous and, apart from fiery condiments, insipid, but it is probably no more so than the food of poorer agricultural peoples everywhere; it is certainly more varied and tasty than that of the Irish peasantry during the earlier part of last century, when they lived on practically nothing except boiled potatoes until the time of the great Potato Famine.

The diets of tropical agricultural tribes have certain other features in common also. Vegetables are always eaten fresh, because they will not keep out of the ground for any length of time, and generally very simply cooked, though the preliminary preparation of some of them, the poisonous manioc, for instance, may require much care and time. Here, for instance, is how a modern West Indian cookery book tells you to cook a yam. "Throw a crop yam into the flames of the fire. When half done, take out and scrape with a piece of broken glass. Repeat this at intervals until the skin is quite white and the yam soft right through when you squeeze it. Butter at once." The condiments that accompany the starchy vegetables are highly spiced, partly to counteract the insipidity of the main foodstuffs, partly also because unless highly spiced they will not keep. The

Pepper Pot of the West Indies, for instance, is not only a very savoury meat dish, but a device for keeping meat good for some time in a tropical climate. The basis of it is fresh or salt pork, boiled up with onions, peppers, sugar and cassaripe, which is an excellently flavoured preservative made, rather surprisingly, by boiling down the highly poisonous extract from the rind of manioc roots: the prussic acid is driven off by the boiling. Every day all left-over meat is put into the pepper pot, which is boiled up daily, and in this way the meat can be kept for weeks.

A diet composed of such a large amount of purely starchy vegetables looks a poor one by our standards. It is apparently short of proteins and fats, and very short of some protective foods such as dairy produce, though it often includes plenty of green vegetables. Its defects were brought out clearly by a careful comparison made by Orr and Gilkes (Med. Research Council, Report No. 155, 1931) between a purely agricultural tribe of East Africa, the Kikuyu, and their pastoral neighbours, the Masai. The physique of the Kikuyu is very poor and they are subject to many diseases, largely as a result of an unbalanced vegetarian diet composed chiefly of millet, maize, sweet potatoes and yams. " Of 17,000 men of one district of the Reserve, who, during 1917, were called up for enrolment in the Carrier Corps, 11,000 were immediately rejected on medical grounds. Following the march of 100 miles to the depot at Nairobi, a further 17 per cent were rejected as physically unfit." (Walter Elliott: *Times Weekly*, May 16, 1929.) The Masai warrior, living chiefly on meat, milk and blood, is at twenty years old five inches taller than the male Kikuyu and twenty-five pounds heavier, and is physically a splendid specimen. One third of the Kikuyu suffer from ulcers, half of them from bone deformations, over a quarter of them from bronchitis, and they are generally a sickly people. Masai boys in Government schools, fed on a largely vegetarian diet similar to that of the Kikuyu, approach the Kikuyu in physique. However, among the Masai, whose diet is unbalanced in the other direction, there is widespread arthritis, little known to the Kikuyu; also the Masai women are so

infertile that their men when possible take Kikuyu wives, the Kikuyu women being very fertile.

This is but one example among very many, and we must not rush to conclude from it that the diet of the vegetarian tropical farmer is always inadequate for maintaining him in good health. It is short of protein by our standards, but we know very little, when all is said, about the physiological requirements of tribes very different physically from ourselves, and it is possible that the protein they get in their diet is perfectly adequate for their requirements in a tropical climate. Then, too, the supplementary foods such as condiments, plant ashes (much eaten by the very fertile Kikuyu women, for instance) and native beer often contain many valuable vitamins and minerals otherwise absent from the diet. Well-meaning missionaries in trying to abolish native beer-drinking orgies have often deprived their converts of a really valuable accessory foodstuff. But certainly the diet of the Kikuyu appears deficient, judging by results. However, against his poor diet can be set the good diets of other tropical agricultural tribes. They all tend to be rather short of calcium, and the small stature of many of these people may perhaps be related to this deficiency in their diet, but as the deficiency is due to the climate, which has the effect of rapidly leaching lime out of the soil, it is difficult to remedy. Maize grown in Kenya, for instance, contains only 0·004 per cent of calcium, as against 0·02 per cent in North American maize. On the other hand, the green leaves eaten by the Kikuyu women are extremely rich in minerals, containing, for example, 0·96 per cent of calcium, whereas spinach contains only 0·067 per cent, while some of their plant ashes, used as substitutes for salt, are the richest known natural source of manganese in food, being from twenty to twenty-five times as rich in this mineral as commercial wheat embryo, our best available source in this country. Nor do all these tribes live on diets deficient in fats. The coconuts of many Pacific islands are an abundant source of fat, and the "palm-oil chop" of West Africa contains, if anything, too much fat for our tastes, while no one could criticise the ground-nut stew of Northern

Nigeria on the grounds of lack of variety. To a substratum of chicken and hard-boiled eggs are added, among other things, " rice, fried onions, fried banana, fresh banana, orange, crumbled ground-nuts, grated coconut, chili, and as many different kinds of pepper as the local market can produce." " It is a meal to munch your way through with slow, discerning enjoyment." These rich and varied West African dishes are the parents of many of the famous dishes of the American South, the West Indies and Brazil, where they were introduced by negro slaves working in the kitchens of the plantation houses.

This pointillist description of methods of farming and of food eaten in various parts of the world is intended to show some of the more important ways in which man has tried to adapt himself to his physical environment. He has two main problems to solve: he must obtain from the resources nature gives him a good, satisfying and nourishing diet to keep himself alive and healthy, and he must do it without overdrawing on those resources. By the extent to which he succeeds in solving these two problems simultaneously we may measure the success of his adaptation to his environment. By this criterion very few peoples are really successfully adapted to their whole environment, at any rate when so many of them as there are at present attempt to live on earth. Perhaps English farmers during the Golden Age of English farming, so attractively described by A. G. Street in *Farmer's Glory*, would come into this category of successfully adapted people, well fed themselves, living on a fertile soil which they kept in good heart. So would some agricultural peoples in other parts of the world, but not a very large number. Our own present diet, better in many ways than those of most of our predecessors because it is much better provided with protective foods, is based, much of it, on wasting assets of soil, either in this country or in the lands overseas from which we draw our food. To that extent then, our present adaptation is not a good one, judged by the human geographer's standards. On the other hand, people abundantly supplied with resources may fail to use all of them, or even to use them well

enough to keep themselves free from deficiency diseases such as rickets and scurvy. It was known that scurvy, which haunted northerly countries for centuries and was called "the most reigning Disease in this Kingdom" in 1696, could be cured by fresh green vegetables and fruits, yet side by side with the disease persisted the belief, taught by Galen and persisting for centuries, that fruit and vegetables gave rise to fevers: "Nowe all fruites generally are noyfulle to man, and do ingender ylle humours, and be oftetymes the cause of putrefied fevers, yf they be moche and contynually eaten" (Sir Thomas Elyot, *The Castel of Health*, 1539). This belief was still alive in the nineteenth century, and fresh fruit and vegetables have only become a recognised part of the good diet in very recent times. It seems, from Drummond and Wilbraham's penetrating study of nutrition in England during the centuries, *The Englishman's Food*, that modern man at any rate is unable to evolve a perfect diet by empirical methods: it seems that habit and tradition, fashions and tastes in food, are far more powerful factors in determining what we shall eat than are our physiological needs. It is only in exceptional circumstances, such as pregnancy, that "cravings" for some special food that the body badly needs are sufficiently strong to overcome our fixed eating habits. Often, too, we may know what we need to eat, and we may very much want to eat it—which of us would not like more meat, eggs, cheese and fruit in our diet today?—but economic or political factors may prevent us from doing as we ought and as we wish. It is the dream of the Human Geographer that one day all men on earth will have abundant, nourishing, tasty food, suited to the climates they live in and the work they do, without overdrawing on the soil's reserve of fertility and without disturbing unduly the balance of nature; but even with all the resources of modern science at our disposal and with a growing knowledge of the working of economic laws, this happy prospect remains little more than a dream. For, as we saw in Chapter II, food comes in the last resort from plants, and plants draw their life from the soil; there is only a limited amount of soil on earth, while the

numbers of men to be fed from it are ever more rapidly and alarmingly increasing. Will the soil be able to respond without damage to the enormous and ever-growing demands that man is making upon it? Are his agricultural systems, outlined in this chapter, capable of almost indefinitely increasing their output? And if the soil fails, what are we to eat? In the next chapters, then, we will consider the soil, that mysterious entity of which we know so little and think so seldom, which yet in the last analysis is the mother of us all.

CHAPTER VIII

THE SOIL (1)

IN the classical fable, Antæus, whenever in the stress of battle he fell and embraced his mother the Earth, sprang up again invigorated; her vitality and strength refreshed him, her life flowed anew through his veins. The Greeks embodied in that fable their whole concept of the unbreakable bond, part physical, part mystical, between man and the earth he lives upon. Is it too fanciful to wonder if they, like Antæus, drew their own amazing vigour of mind and body from their homely earth, through a healthy pagan awareness of the beauty and the mystery, and not merely of the utility, of the soil? "The soil"—the very word shows, by the contemptuous use we make of it, that we moderns have lost that awareness. "I would not soil my hands with it," we say—"night-soil," "washing soiled linen in public"—every phrase betrays us; we have come to despise the soil; we reject it, tread it underfoot as unclean and earthy, sordid, beneath the notice of refined, civilised, intelligent beings such as ourselves. Yet some of our modern authors know better: "Not even clouds," says Karel Capek, "are so diverse, so beautiful, and terrible as the soil under your feet."

For very many of the troubles that now beset mankind, from the rolling yellow floods of the Hoang-ho with their train of death and tragedy to the long-drawn misery of the Dust-Bowl farmer, have overtaken us because we have lost our respect for the soil; we have ceased to think of it in any but crude economic terms, as an intractable medium clumsily devised by nature to complicate the process of growing crops for our own food and profit. How much simpler and pleasanter it would be to grow crops instead by hydroponics, on sterile cinders bathed in nice clean nutrient solutions!—then we would not need to worry with the soil, and the curse of Adam, which is weighing rather

heavily on us at the moment, would be as outmoded as the stage-coach and pack-horse.

The Greeks knew better, as does the modern peasant or farmer who, as we say, "lives close to the soil." For the soil is and remains the mysterious source of all life on land, the end and the beginning of every cycle, the unbreakable link between the inorganic world and the organic, binding man to the earth with a force as inescapable as the force of gravity. In man's relations to the soil are epitomised all his relations to his physical environment, and the soil is, more than any other single feature of the earth on which we live, the direct concern of the bio-geographer.

Why is the soil so important to man? Let us consider its functions a little more fully.

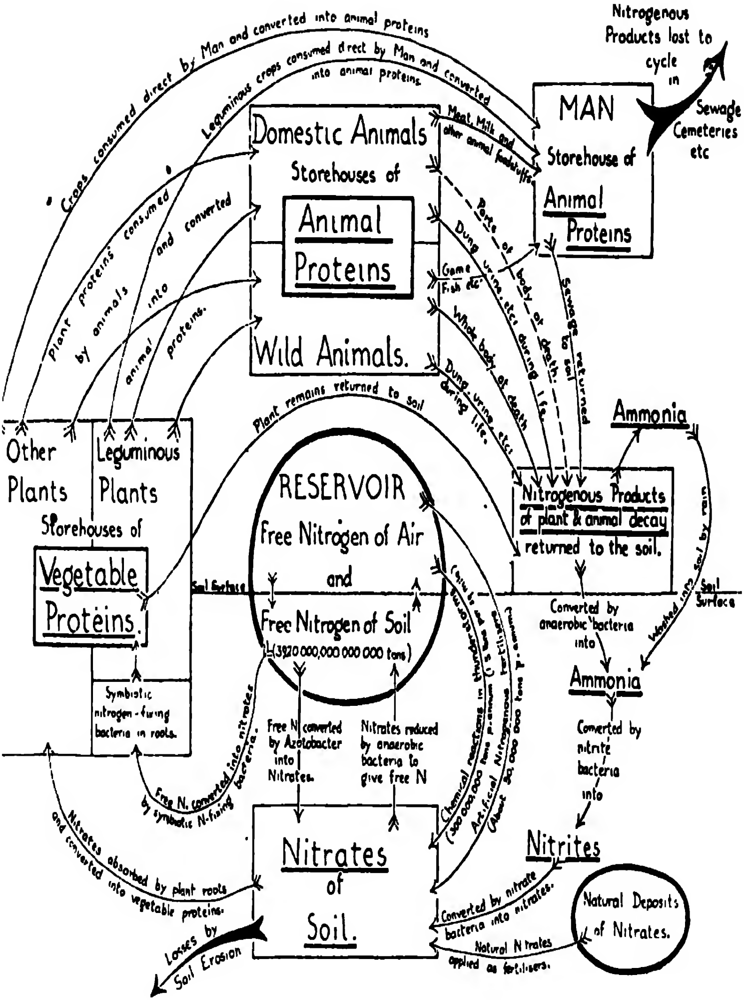
We have seen in Chapter II that all animals must ultimately rely upon green plants to work up the carbohydrates, fats and proteins that they use as food. Plants make these in part from the air, which provides the carbon and oxygen for making sugars, starches and fats; but they also use water, and this has to be got from the soil, by way of the plants' roots. To manufacture proteins, other elements are required besides the carbon, oxygen and hydrogen from the air and water, and these others are only available in very dilute solution in the film of water that encloses each separate particle of soil, or soaks into the fibres of decaying plant remains as if into a sponge. This very dilute solution of simple salts, circulating in the pores and interstices of the soil and drawn in by the roots of plants, is the source of the raw material for the proteins that build up the protoplasm of our bodies and brains, from the sensitive retina of the eye that reads this page, to the skin and muscles of the hand that wrote it. And as our bodies came from the soil, so when we die they should return to it, if they are not hermetically and hygienically sealed in a lead coffin to putrefy instead of rotting cleanly down to humus and reappearing in the bodies of plants and animals.

More specifically, all of the elements and some of the compounds essential to life pass through a cycle of physical and

chemical change in which the atoms of an element retain their identity while passing through a series of combinations. In many of these cycles the element must at some point in the chain be held in the soil. Of compounds that undergo such cycles of change and recombination water is the most conspicuous and universal, passing through the unattractively-named "hydrologic cycle," from the seas to the air above them by evaporation; to the clouds by condensation; to the earth by precipitation; and so back to the sea in rivers formed by the water running off the soil, or in ground-water, the water that sinks into the soil and emerges lower down in springs. So the cycle is completed, the water passing in turn from sea to air to earth and back again to sea. But in its sojourn on the earth, miscalled the "dry land," some of the water for a time, in combination with other simple substances, undergoes miraculous metamorphoses into organic compounds of almost infinite variety, to appear as the mighty host of living things whose physical bodies, endowed with so many inexplicable powers, are yet made of a substance which itself is more than half water. And—this is the point—the water in the organic compounds only enters into the bodies of the living things by way of the soil and the plants that grow on it; the soil forms the link between the inanimate inorganic world and the world of living things.

Another element which passes through a somewhat analogous cycle is nitrogen. Nitrogen exists free in the air in great abundance, but it is an inert gas, a mere diluent for the atmospheric oxygen, and in its free state reluctant to enter into any chemical combinations whatever except under stress of very unusual conditions such as those met with in the air during the passage of a lightning flash. In the nitrogen cycle the atmospheric nitrogen forms the great reservoir supplying all the nitrogen undergoing cyclic changes, just as the sea acts as a reservoir in the hydrologic cycle.

This inert atmospheric nitrogen can be used by certain kinds of bacteria living in the soil; they combine it with other substances to form simple salts of nitrous acid known as nitrites,



THE NITROGEN SPIRAL

and these in turn are worked on by other bacteria which combine them with more oxygen to give salts of nitric acid known as nitrates. There are also bacteria living in nodules on the roots of plants belonging to the family Leguminosae—such plants as clovers, vetches, lupins, peas and beans—which can make the free nitrogen of the air present in the soil combine with other elements to form nitrates. All these bacteria are known collectively as " nitrifying " bacteria.

Nitrates are the only compounds of nitrogen that most plants can use, sucking them in through their roots in very dilute solution in the soil water and building them up into amino-acids and proteins. An animal eats the plant, absorbs the amino-acids in the plant proteins and builds up new proteins from them. During life the animal discharges nitrogenous wastes in its urine and dung : when it dies and its body is left on or near the surface of the soil, or when plants die, other bacteria set to work on the complex nitrogen compounds thus provided, and break the proteins down again into simpler substances. One of these, formed early in the process, is ammonia, the gas which provides the strong smell of decomposing urine and other animal wastes on a manure heap : some of the ammonia escapes into the air, but it is extremely soluble in water and is rapidly washed back into the soil by rain ; then by various chemical reactions its nitrogen is recombined into nitrates once more, and so the cycle repeats itself. It is far more complex than I have suggested here ; the chemistry of the decomposition of many of the nitrogenous compounds that make up the bodies of animals and plants is still not fully understood ; also other bacteria, called " denitrifying " bacteria, may under certain conditions put the cycle into reverse, releasing free nitrogen from combination and returning it to the air again.

The processes of decay that make up one half of the cycle are helped by all sorts of small animals, such as the burying beetles that inter corpses of little creatures like mice and birds, to feast their young upon them at leisure underground : dung beetles that dispose similarly of solid animal excreta ; worms that pull

underground, swallow and digest dead plant refuse: ants and beetles that dismember and devour small corpses of all kinds, and so on. Given a natural life and a natural death and burial, the living bodies of all plants and animals are merely temporary storehouses of nitrogen, as of water: at death they return cleanly and neatly to the earth that gave them life, disappearing almost without trace, and their component elements go back into the common stock in the soil and the air. It is rare to find the dead body of a wild animal; it disintegrates and disappears almost at once.

It is only civilised man that breaks the cycle. He returns his body wastes and those of his animals, everything he has derived from the food he eats, not to the earth that gave it but to the sea, polluting the rivers that carry it till they run sluggish with sewage, and throwing the minerals he has drawn from the soil irretrievably into the abyss of ocean. He even seals his dead body away from the surface soil to which it owes every atom of which it was made. In the Alps, where soil is shallow and good soil too valuable to be wasted in pretentious cemeteries, the dead are buried in shallow graves for a decade or two, no more; at the end of that time they are disinterred as clean white bones, to be stored in the village charnel-house so that the grave may be used again. This is the natural way to dispose of our animal bodies; the earth receives gladly what the earth gave, and in due time gives it back again; there is no waste, and none of the normal cycles of change and renewal are arbitrarily broken. But in the unnaturally crowded warrens of humanity that are our towns such methods of disposing of the dead are frowned upon because of the risks to health that they may entail; the more objective view, that it might be better in the long run to conserve soil fertility and keep population from increasing too rapidly, is unpopular with orthodox Public Health authorities. But in nature nitrogen, like water and many other substances, passes through the soil during one phase of the eternally revolving cycle of change and recombination, from the physical world to the living bodies of plants and animals and back, over and over

again, time without end. Wild animals and uncivilised men live frugally on the turnover of their small income; it is only civilised man who has taken to living extravagantly on his capital.

The soil, then, through the hydrologic cycle, the nitrogen cycle, and other similar cycles, is the link between the inorganic world of the rocks, the air, the sea water and the rain, and the organic world of bacteria, plants, animals and men. It is a vast chemical laboratory in which all sorts of compounds, organic and inorganic, are perpetually being synthesised, broken down, or changed into other compounds, extracted by plants and recombined into new substances, or given back to the common stock by animals and plants when their life is ended to be worked up once more by the busy frugal soil chemists into food for new plants and new men. It is all a perfectly balanced process, with no mess and no waste; though some of the substances elaborated in the soil eventually pass to the sea in the water of the rivers, their loss is made good by new substances that pass slowly into the soil in the ordinary processes of weathering of the rocks and mineral soil particles (see the volume in this series on Physiography). Nothing is lost, if man does not interfere: the soil retains its fertility, that is, it retains a stock of plant foods sufficient to maintain an exact balance with the plants and animals which live and grow upon it and, dying, turn the chemicals they have borrowed for the period of their lives back into the common storehouse in the soil. In fact, so carefully is the balance poised between the soil and the living things upon it that it is impossible to separate one from the other; any change in the soil provokes a correlated change in the plants, and so in the animals, that live upon it, and vice versa. When man removes natural vegetation, clearing forest to grow crops, ploughing grass land or draining swamps, the balance is upset: the soil itself changes with the change in its covering, and it can only be kept in more or less the same condition of fertility by feeding it with manure to replace the food it formerly got from the decaying natural vegetation. For the soil is alive, and

must be fed; it feeds itself partly like an animal, by ingesting complex organic substances and digesting them, and partly like a plant, by soaking up dilute solutions of inorganic salts and building them up into other compounds.

Perhaps you have not before thought of the soil as alive. It looks inert; it has no power of locomotion; it is heavy and passively resistant when we work it with a spade or a plough. Yet in fact what we see at a casual glance is only its inorganic skeleton, its bones and carapace, a mass of lifeless stony fragments ranging in size from large pebbles to infinitesimal particles of clay, and in composition through the gamut of complex minerals found in the rocks. But take a fork and turn over a clod, in pasture or woodland where the soil is more nearly in its natural state. As you turn it a worm shrinks back into its burrow; a wireworm is left stiffly twisting from side to side; a centipede scuttles away over the broken earth. These are a very few of the larger soil animals, making up the so-called "macro-fauna" of the soil, which includes mice, moles, worms, rabbits, insects of many kinds and so on. The "macro-flora" of larger plants shows itself at once, too, in tufts and strings of broken grass and tree roots, a dense sod of them perhaps, and a few seeds. But the macro-fauna and macro-flora that you can see with the eye are of considerably less importance than the micro-fauna and micro-flora, which you cannot see, since they are composed of bacteria, protozoa, unicellular green plants, fungi and so on. It is the innumerable millions of them, living and dead, which carry on the useful activities of the soil and are responsible for the valuable chemical reactions which it performs. The macro-fauna and flora, on the other hand, do important work in improving its physical condition, aerating it with their burrows, mixing it, pulling down dead leaves, decaying grass stems and animal remains into it or bringing up fresh soil from deeper layers to the surface.

The quantity of living things in the soil, particularly in good fertile soil, is astonishing.

For instance, in an ordinary field these are several million

bacteria in every gram of topsoil, say half a teaspoonful. If it is garden soil, liberally manured, there will be up to 200 million in the same amount, their actual numbers fluctuating with the season of the year.

And all these living things are working together, living, multiplying, feeding, digesting, dying, decaying, to produce that extraordinarily complex, mysterious, life-giving substance that we call "soil."

Let us look a little more closely still at what is going on in the soil. To begin with, we should not think of the soil alone but of the soil together with the plants growing on and in it, as a single complex living entity of which the two members, soil and plants, live together in an indissoluble companionship like a happily-married husband and wife, each responding to and altered by every action of the other. Now the kind of vegetation that grows in any place is very largely determined by the climate of that place; warm humid climates favour forests, cold dry windy places are given over to low-growing grasses and herbs, and so on. Within the limits of one climatic zone, however, local variations in soil and exposure may produce variations in the vegetation; ill-drained hollows hold swamps and fenny pools, dark shady hillsides trees, sunny dry ones grasses, and so on. Apart from these local peculiarities the vegetation is determined by the climate, the soil is formed by the vegetation, and the three factors—underlying rock and land-forms, climate, and vegetation—act and interact to produce a soil which represents the result of a delicate balance of influences among the three.

Consider what happens, for instance, in a cold damp climate with long, snowy, dark winters and short, warm, moist summers with long days, such a climate as prevails over immense stretches of country in the sub-Arctic latitudes of Canada and Siberia. The rocks here vary from very hard, strongly-folded, ancient igneous and metamorphic rocks to fairly recent thick flat sediments; but the characteristic vegetation everywhere is coniferous forest of spruces, firs, pines and larches, and the typical soil everywhere is grey, infertile and sandy, a soil known by its

Russian name of "podsol" or ash soil. Here from year's end to year's end, undisturbed, the hard pine and fir needles fall to the ground to decay very slowly through the short cold days of winter, contributing but little fresh organic matter each summer to the uppermost layers of the soil. What products of decay they do supply are mostly acidic, and are washed down into the soil by the summer rain and the melting snow water of spring, for in these high latitudes it is never warm enough for much water to evaporate from the surface of the soil, and water in the soil is moving constantly downwards. Seeping down through the upper layers this slightly acid rainwater dissolves out most of the minerals from the soil and carries them down with it, leaving at last only the bare resistant quartz grains whose grey colour characterises the upper layers of the soil. There is little humus, partly-decayed organic matter, to bind the grains together, and the soil is very light, friable, easily worked and hungry for manure. At lower levels, in the subsoil, the salts that the acid rainwater leached out of the upper layers are precipitated as the result of a great variety of chemical reactions, and the ground here is enriched with potential plant foods, and more compact, because the very fine particles also washed out of the upper layers by the rain come to rest here. Here, too, feed the deeper tree roots, sucking in the percolating water and salts through their root hairs, to drive it up to the surface again through the vessels in their trunks and finally, retaining the salts to build their own wood and leaves, transpiring the water back into the air. So the circulation of water and salts goes on: downwards in the percolating rainwater from the slowly decaying pine needles and dead wood on the surface, leaching the pale impoverished upper layers of soil as it goes: upwards in the tree roots and trunks, building up again into leaves and wood which fall to the ground and so complete the cycle.

Whatever rock and vegetation the process begins with, after a lapse of many centuries in a climate of this kind the end products will be the same: coniferous forests, the climax of the vegetational succession, on the surface, and ash-grey podsols

round their roots. But the whole system is in a state of precarious equilibrium: fell the trees, plough the light thin soil, and the balance is upset. Now the hungry sands must be fed with manure instead of pine needles; more manure must be added to counterbalance the minerals and organic matter carried off in the crops, and more still to counterbalance the minerals lost by leaching, lost permanently because there are no longer the tree roots to bring them up again to the surface. Something may be done by deep ploughing to stir up the richer lower layers of the soil, but podsols are hungry unproductive soils at best, and the climate that produces them is not well suited to crops. They are better left under their dark monotonous forests which, if man must use them and if he manages them wisely, will give him a regular yearly crop of excellent soft-wood timber.

In England, where the climate is not so extreme as in Russia or Canada, there are podsolic soils to be seen on some of our sandy heaths, where the local rocks are poor sands that allow only hardy coniferous trees to grow well. Ashdown Forest, Bagshot Heath, and the East Anglian Breck have podsolic soils with a thin surface layer blackened with decaying plant remains and then a considerable thickness of light sand, leached grey even when the parent sands are bright yellow or red. The film of iron oxide that gives the colour has been dissolved off the grains in the upper layers by the percolating ground water. The west and north of England, Scotland and Wales tend to have podsolic soils wherever there are fir or pine forests.

In these cool moist climates, where the prevailing direction of the soil water is downward and the upper layers of the soil are much leached, soils tend to be very poor in lime, because carbonate of lime is very readily soluble in even slightly acid solutions and so is one of the very first minerals to disappear from the upper part of the soil. Soils in which this happens are classed together as non-lime-accumulating soils, or "pedalfers." In warmer, drier climates, on the other hand, taking the average over the year there is often on the total a net upward movement of water and salts in the soil, because during the

whole year or a good part of it the soil surface is losing more water to the air above it by evaporation than it gets from the rain. This happens, for instance, in the American prairies and the Russian steppes, where the natural vegetation is grass. In such climates salts tend to collect in the higher layers of the soil, but very slowly, since grass by its decay does not provide a very great amount of organic material. Since lime is one of the most conspicuous of the salts that collects in the top soil, these soils are classed as lime-accumulating, or "pedocals."

Soils like these are immensely rich when first ploughed, owing to this surface accumulation of salts, but they are not easily regenerated once the natural sod is removed, and being light in texture because of the abundant plant remains which they contain they are easily broken down to dust and blown away by the wind, if their surface is left uncovered during the long severe droughts that are a regular feature of the climate in the regions where these soils evolve. Hence the Black Earth lands of Russia, and the black lands of the Canadian and American prairies, have some of the most fertile soil in the whole world, but also some of the soil most easily destroyed by faulty management.

I do not propose here to deal in detail with all the different kinds of soil that are to be found over the world; this has already been done excellently in other books, some of which are mentioned in the bibliography at the end of Chapter X. I am concerned here only to make clear the function that the soil fulfils as a part of the physical environment of man. As we saw in Chapter V, the enormous increase in the numbers of men on earth that has taken place was only made possible by a change in man's ways of getting his food, when he ceased to rely on the natural increase of wild plants and animals and took to growing plants and rearing animals for his own use entirely. In this way he has been able to increase enormously the amount of human food that can be produced from each acre of productive soil. But to do it he must use soil which was formerly in a finely-adjusted state of equilibrium with its own natural vegetation; he must

destroy the natural vegetation and replace it with an artificial one; moreover, the artificial one cannot be allowed to die, decay and reseed itself naturally but much of it—often, too, the part which contains most of the minerals—is removed entirely from the soil that grew it. The products of its digestion and decay are not returned to the soil, but washed down sewers and into rivers to be lost for ever in the sea; the water and nitrogen cycles are roughly ruptured; the whole finely poised balance is thrown out of adjustment. Small wonder that in the process the soil only too often degenerates, loses its fertility, and in extreme cases disintegrates and is blown or washed bodily away.

In very few places on earth has man, by an age-long process of trial and error, evolved an artificial routine which succeeds in imitating the natural one sufficiently well to hold the soil in a precarious state of fertility while maintaining large numbers of men by its fruits. It is significant that in one of these places, China, the people are almost all peasant farmers, living on the produce of their own small patch of soil and selling little or nothing off it, while in the other, Western Europe, the same held good until recently, and the recent spectacular increases in population in some parts of Europe, such as this country, have been made possible because it is so easy for Europe to import food from new lands overseas: many of the people of England and Wales, Holland and Switzerland are not really being fed from their own soil at all, but from the soils of Canada, the United States and Argentina. We owe the new countries a debt, not only for the food they have sent us, but for the protection they have thereby afforded our own soils.

Never before has the soil of the world been called upon to produce such gargantuan quantities of food for man as it has been in the last century; never before has the tractor, burning mineral oil and producing no manure, been employed over vast areas to replace animals and men in the work of tilling the soil; never before have the fruits of the soil, wheat, rice, maize, meat and milk, been regularly taken hundreds, even thousands, of miles away from the soils that grew them, to be consumed by

teeming city populations whose waste products are washed down sewers into the sea. Never before has the soil been regarded by the men that work it more as a rather tiresome piece of factory machinery than as a living thing. But never before, too, has the intricacy of the problem been so fully realised; we know now what we are doing, at least in general outline, and we are presumably intelligent enough to evolve ways to avoid the worst of the consequences likely to follow on our world-wide disruption of natural fertility cycles and natural processes. The grave question still remains, however: have we learnt to realise what we are doing in time?—have we not already allowed our numbers to grow beyond the point where the soil can support them without loss?—and is there any hope, in face of the terrifying rapidity with which the human race is now multiplying, that we can save the soil—and ourselves—before it is too late? The question of the rate of increase of the human race is largely a social one, and outside the scope of this small book though not outside the scope of Biogeography, but in the following chapters we will see how the soil is reacting to the immense demands now being made upon it, and how we can alter our present practices to conform more closely to natural laws. It is, however, much easier to suggest what ought to be done than to suggest ways to do it in the world of reality, where a man's present profit is apt to loom larger on his horizon than the problematical future of the human race; even if he knows the facts, he is apt to think that what little he can do will have no visible effect on the solution of a problem of such colossal magnitude.

One of the ways to attack this further difficulty is to educate as many people as possible in the facts that underlie the problem, so that they fully appreciate its vastness, its complexity, and the disastrous consequences of failure to find an adequate solution. In teaching yourself Biogeography you at least are likely to learn how matters stand, and it is my hope that this book may make some small contribution towards that wider general education in the facts of our relation to the earth which is our only hope

for correcting that relation in the future. As I see it, we have got ourselves into a difficult, dangerous mess, through ignorance and greed in exploiting our physical environment, particularly the soil; we can only get out of that mess by making a deliberate, far-sighted, intelligent and very costly attempt to readjust the relations, at present so strained, between ourselves and our physical environment. It is time that we reconsidered our values, relegating material wealth to a lower place in the scale than it at present holds for most of us; we must regain our respect for the soil and for the other living things that share this earth with us, to whom we owe our very life; and not until we have done this, and acted upon our new-found convictions, shall we regain the health and happiness, the vitality and strength that Antæus found in the embrace of his mother the Earth. This process of replanning our relations with the whole of our natural environment, and with the soil in particular, is above all the province of the geographer.

CHAPTER IX

THE SOIL (2)

WE saw in the last chapter that the soil's main function where man is concerned is to act as an entrepôt for a huge variety of chemical elements and compounds, storing them and exchanging them between the organic and the inorganic worlds. We saw too that our modern civilisation, with its sewage works and cemeteries, makes wasteful use of the soil's gifts, though at the same time these wasteful ways of getting rid of unwanted organic matter help to ensure good health among city dwellers, who are no longer subject at intervals to epidemics of cholera, typhoid and other deadly diseases that used to keep down their numbers in earlier days when modern sanitation was unknown. We have, in fact, by improving sanitation and plumbing, made it easy for men to live together in vastly increased numbers, without at the same time making sure that the drain on the soil caused both by these increased numbers and by the improved sanitation is being made good in other ways. In this chapter we shall see how the effects of that drain on the soil show themselves.

We have hitherto looked at the question of the disposal of plant and animal matter solely from the point of view of the minerals that it may contain. But this does not give us a complete picture of what is going on. The physical properties of these plant and animal bodies are of fully as much importance as their chemical make-up. Where the soil is concerned, we must not make the mistake of thinking of the chemical elements and compounds that we have been discussing as existing in a pure state, as though in bottles on a laboratory shelf; we must think of them as dead leaves, fallen tree trunks, grass roots, dry bones, horse manure, straw, cow dung, feathers, hair, eggshells, and a host of other substances of the kind. These substances

are of value in the soil, not alone because they give it back the nitrogen, phosphorus, lime and other elements that their living owners had borrowed for a time, but also because they have all sorts of effects, both when intact and when partially decayed, on the physical structure and properties of the soil. They lighten it if it is clayey, help to bind it if it is sandy, make it airy or moist, change its colour and its capacity for holding moisture, alter its temperature, and so on. These effects are every bit as important as the more purely chemical ones discussed in the last chapter.

The skeleton of the soil, its dead, inorganic skeleton, consists of mineral particles derived by the ordinary processes of mechanical and chemical weathering from the parent rock. The larger of these fragments are actual lumps of the parent rock, little changed in chemical composition; the smaller are often single crystals, whole or broken, of individual minerals. Some of these minerals are easily identified. *Quartz* crystals, in the form of sand, are familiar to gardeners in mid-Sussex, much of Surrey, Devonshire and many other places where the native rock is sandstone or granite. Quartz is a mineral that successfully resists the action of most chemical reagents, and it is so hard that it is not easily worn down by mechanical processes, so that it tends to accumulate in old or impoverished soils. It is very common in deserts because it is the sole survivor of the unceasing wear and tear of the elements on exposed rock surfaces, and its grains remain too large to be carried up in the air by the wind and wafted away to wetter places.

Apart from quartz, many gardeners in the Midlands and in low-lying river valleys are only too familiar with *clay*—"clay like lead, squelching and primeval clay out of which coldness oozes; which yields under the spade like chewing-gum, which bakes in the sun and gets sour in the shade; ill-tempered, unmalleable, greasy, and sticky like plaster of Paris, slippery like a snake and dry like a brick, impermeable like tin, and heavy like lead." Clay occurs in particles so minute that they do not settle, like sand does, if the clay is stirred up in water; it coheres

in masses of such close texture that water cannot seep through their infinitesimal pores, so that clay soils are often ill-drained, sticky, and full of all the vices that Capek attributes to them in the passage just quoted. But clays possess a good store of plant foods and hold water well, so that clay soils are often moist and bearing good crops of grass or cereals when the plants on arid quartz or limestone soils are perishing from drought.

Another soil mineral that most of us can recognise is *lime*; some of the thin soils on the Chilterns and the Downs are made up almost wholly of it, white chalk turned a little greyer and a little less forbidding by a miserly addition of grass blades and plant roots from the scanty pastures that it nourishes. Many soils in the west and north of England, however, on sandstones and other rocks that contain little or no lime, suffer badly from a lack of it and so are sour and infertile.

Quartz, clay and lime are easy to recognise in soils, especially in those which have too much of any one of them. However, if we were to pound up quartz, clay and lime into grains of suitable sizes, and add suitable amounts of other minerals obtained similarly direct from their parent rock, the resulting mixture would not be crumbly, friable and porous like good soil, but a lifeless mineral powder, unresponsive, sodden when wet and dusty when dry, not a living soil but a dead one, for "soil formation," says Joffé, "has its beginning with the advent of life."

The missing substance in our dead mineral powder, the substance which cannot by any known means be made from inorganic compounds but only by living things, is called *humus*. Humus, so far as we know, has an extremely complicated and probably variable chemical composition, so that it is impossible to define it in exact terms. But it is easy to recognise. You will find fairly pure humus in a really well rotted old manure-heap, or as the end product of a properly constructed and managed compost-heap. It is a soft, moist, spongy, black or dark brown material, practically odourless; if it smells of manure, decomposition of the plant and animal wastes that went into the heap has not gone far enough. It has no obvious structure; the plant tissues

that went to form it are no longer recognisable as such; crush a bit between your fingers and it dissolves into a smear as soft as face powder. When quite dry it is dusty, but it is seldom dry, for it has an immense capacity for soaking up and retaining water, up to many times its own weight of it.

Humus is undoubtedly the most valuable single material in the soil, though in a mixture of such enormous complexity as soil it is difficult to single out any one component as more necessary than another. Its physical properties are particularly valuable; it lightens clay soils, making them more porous and easier to work; it binds sandy soils and helps them to retain water and plant foods; it warms cold soils and lessens the extremes of temperature to which light soils are subject. There is no soil, with the possible exception of the black soils of Russia, the American prairies and our own Fens, all of which are already extremely rich in it, that cannot be improved in physical condition by adding humus. At the same time the humus acts as a reservoir of plant foods, and is the medium in which many of the important chemical reactions occur that are characteristic of the soil. There is no soil—again with the possible exceptions just mentioned—that will not be made more fertile and richer in available plant foods by adding humus.

Thus it is essential to return organic wastes to the soil not only for their chemical content but more particularly because they are the raw material of humus. If these wastes are not regularly returned to the soil, to be converted into humus by the earthworms and other living dwellers in the soil, its humus content begins to decline. The minerals that the organic wastes might have supplied can be provided by using artificial fertilisers, but there is no artificial substitute for humus. As soils decline in humus content, with few and doubtful exceptions they decline in fertility. They become cloddy, lose their puffy, crumby structure, and become harder to work and maintain in good tilth. They dry out more readily in drought. They become compact and poorly aerated. And steadily, slowly at first and then more rapidly, the yield of the crops grown on them falls.

This is the first clear indication that something is wrong with the soil. On a properly maintained soil crop yields will fluctuate from year to year with good and bad seasons, but the average yield over a long period should remain steady or even rise, since plant breeders and agricultural research workers of every kind are steadily raising potential yields by breeding heavier-cropping and disease-resistant strains, evolving new techniques, better fertilisers and innumerable other devices for increasing production per acre. Yet in almost every part of the world for which figures are available the average yield per acre of the staple crops is not rising; it is either steady or on the decline. There are other more obvious reasons, besides a decline in soil fertility, to account for a decreasing yield, especially since the late war: they include pests and diseases, impoverishment of farmers and destruction of their resources, and the spread of a crop from rich land into land not so well suited for its cultivation. But even taking all these into account the slow but steady decline in yield, over so large a part of the globe, in the face of all that modern science has learnt and has done to increase it, should give us food for very serious thought indeed—with mankind increasing by millions every year and no new lands left to bring under the plough. It seems at least possible that the decline is connected with our greedy thoughtless exploitation of the soil, in course of which we draw ever more heavily on its capital of fertility and fail to repay all that we have borrowed.

This is the first stage. Later stages are more spectacular, more alarming, and so more likely to goad us belatedly into taking action to retrieve a little of the damage we have done. These later stages are at present practically unknown to us in this country and in Western Europe, but they are only too familiar to people in the rest of the world. These further stages in the breakdown of the soil under stress of faulty usage are known collectively as *soil erosion.* Soil erosion is now, tragically, as familiar a feature of the landscape as trees or fences to thousands of farmers all over the world, in much of the United States, Mexico, Central and South America, Africa, Australia and New

Zealand, the Mediterranean lands of Europe, the Near and Middle East, India and China. In fact the parts of the world still comparatively free from soil erosion are very few indeed; they include lands with too cold a climate for cultivation—Greenland and Antarctica, of course, and the tundras of Asiatic Russia and the Barren Lands of North America: the few lands which still keep their sombre aboriginal forests, of which the Canadian and Russian temperate evergreen forests make up one large section and the steamy Amazon rain-forests another: the deserts, which have no true soil because they hold so little life; and are subject to intermittent but very destructive erosion similar to soil erosion in moister lands: and the few farming regions of the world, notably Western Europe and parts of North America and China, which have evolved a truly conservative form of agriculture and have not exported food in large quantities away from their own people, so that they have managed to keep their soil almost undamaged up to the present.

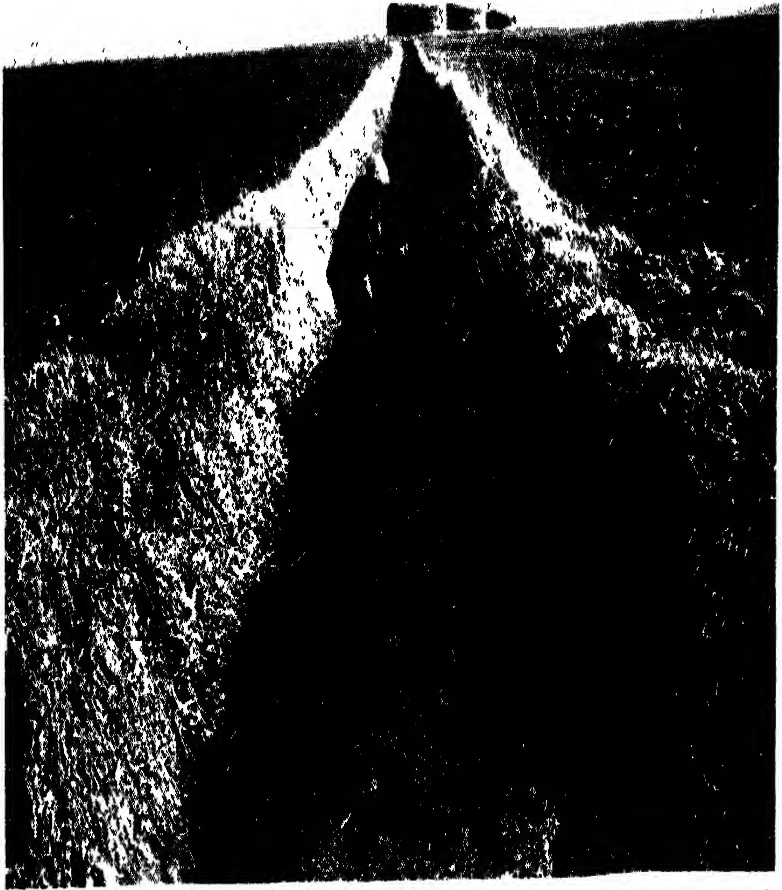
Soil erosion is of two principal kinds, erosion by water and erosion by wind. Erosion by water is most likely to happen in lands where the rain falls in short heavy showers, which when they fall on bare and deteriorated soil are far more destructive than a light drizzle. When next we feel disposed to complain about our grey sunless days, with clouds overhead and pavements wet underfoot, or earth sticky in the fields, let us instead be thankful that our gentle continuous rain is kind to the soil of our fields, and does not wash it into the rivers if we mismanage it, as do the torrential downpours which are so common in most other parts of the world.

There are few other parts of the world where the rain is so gentle and so prolonged as it is with us in Western Europe, few parts where it is also so well-distributed through the year that the soil seldom dries out completely enough to be vulnerable to wind erosion instead of erosion by water. In wind erosion, the top layer of the soil is blown instead of being washed away, to form clouds of fine penetrating dust, dust that at the end of the 1930's blew all the way from the drought-stricken High Plains to

the Capitol at Washington and first jerked awake the whole American people to notice what was happening to their soils. In Australia during the recent droughts, fine red dust from the farm and grazing lands of the interior fell on the decks of ships hundreds of miles out to sea. In winter at Pekin, according to Osbert Sitwell, "the golden dust-clouds whirl across Eastern Asia from the Gobi Desert, and an icy wind insinuates a layer of dust between the pages of every book in the house. . . . A thick golden haze blurs the outline of roof and wall and tree until you are a few yards off them." And in our own Fens, in a high wind after drought, the ditches fill with fine black dust blown off the bare fields of winter, for the Fen soils, like the Prairie soils, are very rich in humus, and humus, being lighter than quartz or chalk, is the first to go when wind erosion starts. Thus the best soils are likely to suffer most from wind erosion.

This, in fact, is one of its most disastrous results; the very substance which by its presence protects soils from erosion is most easily removed when, by bad management, those soils are exposed to erosion by wind. Wind removes the fine light particles, leaving the coarse heavy ones behind. Besides humus, it blows away the fine clay particles which also act as a binder for the soil; these, too, are richer in plant foods than the quartz and other coarse particles left behind. The final result of constant wind erosion is a bare and roughened surface covered with those stones which were too large to move. It tends to become a stony desert even if there is an appreciable rainfall because any particles small enough to begin the formation of soil are whirled away in one of the wind storms which are typical of such a barren landscape.

These, then, are the first stages of visible erosion of the soil: the wholesale removal, either by water or by wind, of the finer, lighter particles from all of the uppermost layer. Wind erosion is spectacular, even in its early stages; water erosion is not necessarily so, since it begins with an insidious, ubiquitous sliding of the finer particles into the ditches and streams, and there is



(Photo: News Chronicle.

WIND EROSION IN THE FENLAND

A drainage ditch being filled with humus blown off the fields

nothing but the mud, clouding water which should run clear, to show that all is not well with the soil.

This stage consists of the process known as *sheet erosion*, but if nothing is done to check sheet erosion it is soon followed by the even more destructive process known as *gully erosion*, which removes large masses of topsoil and even of subsoil bodily into the rivers. The processes involved are these. Wind erosion and sheet erosion by water leave the soil less able to withstand further onslaughts. It has even less humus; its finer particles have gone; if the erosion has gone on for a long time without being noticed and checked a good deal of the most fertile, friable, absorbent uppermost part of the topsoil may have vanished already into the air or the streams before gully erosion begins on any scale large enough to attract attention. The soil left behind is now less able to absorb the water that falls upon it as rain; without any change in the kind or amount of rainfall the ratio between the amount of water running off the soil and that retained by it begins to alter for the worse; more water runs off, less soaks in. The soil begins to get drier; the water table falls; the vegetation that formerly held it together begins to degenerate. Meanwhile, the run-off water has its capacity for erosion increased; instead of slipping off in sheets it begins to collect into runnels; these start to wear away their beds, and so steepen the slopes from the cultivated fields down which the water pours after a heavy shower of rain. Gradually a steep-sided gully is formed, cutting downwards into the subsoil and eating back ever further and further at its head into the carelessly-cultivated land or over-grazed pasture that first allowed it to form.

As the gullies deepen, they act as field drains in the already drying land. The water table falls further, arching down beneath the gully rims to the level of the gully floor, and so the ominous cycle repeats itself. In many eroded countries, according to Jacks and Whyte, the authors of *The Rape of the Earth*, "drought has come to stay, regardless of the weather."

Sheet and gully erosion by water are most likely to happen in

upland country where there is a slope for the water to run down. They are not so likely to affect flat country, which is more likely to be eroded by wind than by water. In the United States it is the hilly Eastern and Western States that suffer most from gully erosion of their cultivated lands: the soils of the flat Middle West and the Great Plains are more likely to be blown away than washed away. In our own Fens water erosion is almost non-existent, because the land is so flat and the water-table already so high that flooding is a very much more likely hazard than gully erosion. Moreover, the hedges that our ancestors planted in our hillier lands, dividing the slopes up into small plots well protected from sweeping winds or the wash of heavy rain, are one of the best insurances we have against erosion of our soils. Grubbing up hedges in our present enthusiasm for making larger arable fields, cheaper and easier to work by machinery, is likely to expose our soils to dangers that they have hitherto happily escaped.

Since flat lands are not much exposed to erosion by water, one might think that in all reasonably moist climates they would be spared the more spectacular consequences of mismanagement. This, unfortunately, is not so at all. Many of the best and richest soils, on flat river alluvium and piedmont plains, suffer badly from the after-effects of water erosion on the slopes above them. The silt washed down from eroding soils is more than the river can carry except when in spate; as the current slackens where the stream debouches into flatter ground, or as the rain stops and the spate subsides, this load of silt is dumped in the lower part of the rivers' courses, with disastrous consequences. Good uneroded land in the valleys is covered with it and so made useless. The silt chokes the fish in the streams; it hinders navigation where it is left as shoals and sandbanks in the larger river beds; it fills reservoirs used for drinking water, hydro-electric power or flood control, and raises the beds of the rivers in their lower reaches above the level of the surrounding country so that the floods become at the same time more disastrous and more difficult to control.

Then, too, as we have seen, the eroding soil in the higher valleys is throwing off a larger and larger proportion of the rain water that used to sink gently into the ground when it still retained its spongy topsoil. The very processes that lead to soil erosion in the first place, particularly felling of forests on sloping land near the watersheds, also make the water run more swiftly off the land after rain; natural pasture and, still more, forest, with its floor of dead leaves and absorbent leaf mould full of humus, soak the rain up gently and pass it on gradually into the soil and the subsoil with little loss, whereas on bare ground there is nothing to break the force of the rain when it first falls, and ever less and less topsoil to absorb the water and keep it from pouring unchecked down the slopes. Soil erosion is a self-perpetuating process of appalling malignance which, if once it is allowed to start, will go on with ever-increasing momentum, becoming ever more difficult and costly to check. So far has it gone already in many lands that some of their soils are even now beyond redemption except at prohibitive cost in money and labour and under social and political conditions which few countries in the world could tolerate. And all too many of the countries where soil erosion is not yet as bad as this have already embarked on the broad and easy road that leads to destruction; without swift and effective action their soils may soon have gone too far to save.

This, then, is the history of soil erosion as it has been written in continent after continent, country after country, since man left off being a hunter and took to farming instead, so that his numbers increased. In early days there were very few men; the world was still wide and its resources ample for all. Man's puny efforts scarcely stirred a ripple on the surface of the great smooth current of natural processes. Shifting cultivation, which was practised by the first farmers, is only wasteful and destructive if, as in our less spacious days, the ground has to be re-used so often that it has no time to recover completely by the regeneration of the natural vegetation. There was always plenty of land, and virgin forest is easier to clear than the secondary growth that

springs up at first on an abandoned clearing, so probably the Mesolithic folk and their successors who farmed like this preferred to move on and fell new forest rather than return to their derelict plots. When first trees are felled on steep hillsides the soil lies open to rain-wash and gullying, but again, if there is plenty of land, people do not cultivate steep hillsides from choice, since flat valley floors have richer soil and are much easier to work. Lastly, when only small temporary clearings are made in a forest there are abundant seed-trees left nearby, and young seedlings will quickly spring up and fill the clearing. It is different when much land is cleared and the young growth is repeatedly felled before it has time to set seed, so that there are no old trees left nearby to re-seed the deserted plots. This is what has happened in all the countries with a long history of sedentary farming. If we want to grow a forest in this country it is no use leaving a piece of ground to seed itself: it will soon be covered, not with oak or beech trees, but with hazel or hawthorn scrub, because there are probably hazel nuts and haws to be had in plenty in the neighbouring hedges but few if any acorns or beech mast. If we want the trees we must plant them from seed imported into the area. But as we know from the records of pollen analysis quoted in Chapter VII, in the days of our Mesolithic ancestors the mixed oak forest easily engulfed the tiny clearings that those early farmers made in it, and probably, by the end of the few decades that it takes an oak tree to grow twenty or thirty feet high, all trace of the clearing had vanished. In the heat and damp of the Amazon valley abandoned clearings are swallowed up by vegetation in a year or so, though at first the trees in the clearing are of other species than those that make up the surrounding high forest, ones that can thrive better than the true forest trees in the brighter light and greater dryness of the clearing. However, where clearings have to be recultivated every few years because of pressure of population on the land the forest never gets a chance to pass beyond this preliminary stage, and alters completely in character as a result. This has happened over much of Tropical Asia and Africa.

Probably nowhere has forest been so lavishly destroyed as it was by the European settlers in North America, just as never in the history of the world has there been so wanton and ghastly a slaughter of wild animals as that of the millions of buffalo on the Great Plains after the coming of the railways, a slaughter the story of which makes one almost despair of human nature. The North American settlers came from countries whose forests had been cleared centuries ago, and many of them were used to working small farms, carefully tended, in regions where land was very valuable and always scarce. If you were fortunate enough to own a farm in these countries, and abused its soil, there was no hope of getting another. In the new continent there was land—rich virgin land, in fabulous quantities—to be had for the asking, but it was covered with trees. So, slowly at first when the settlers were few and Indians kept the forest ways, ever more rapidly as immigrants thronged in from Europe and the Indians were driven back or exterminated, the trees fell before the axe and the saw and the even more devastating fires of the farmers.

"The east wind on the Lake for a generation
Smelled of the smoke out of Michigan—out of the pines."

So they perished in millions, trees of colossal size that had been maturing for centuries—oaks and pines, maples, hemlock, spruce, black walnut—trees that would be worth millions in our wood-starved modern days, but that were then thought of merely as tiresome weeds, trees a hundred and fifty or two hundred feet high, with the long straight branchless trunks that trees develop in crowded virgin forests; and after them, in the blackened, stump-scarred clearings, the settlers sowed their corn. Land was still cheap—cheap land has been the curse of North America since the days of the *Mayflower*—and so when the stored fertility of centuries was gone in a few seasons from the bared soil it was cheaper and easier to clear the trees off more land than to put the soil of the old clearing back into good condition. Sometimes stolid Pennsylvania Germans and others with a sound conservative farming tradition moved on to the abandoned lands and brought them back into bearing: more often they were

simply left for the rain to do its worst with the exposed, exhausted soil, and so the great and tragic history of soil erosion in North America began. Always it has been the cheap land that has been the villain of the piece; had land been scarce and dear, and labour cheap, the land would have been properly appreciated and properly treated. The cheapness and abundance of land must be held largely responsible for the North American's traditional squandering of natural resources—soil, wood, buffalo, oil—that would horrify us much more in our overcrowded, less generous lands if we did not already owe so much of our own prosperity to it.

Now as America fills up with more and more people she has come to the end of her virgin soils and is beginning to realise that she too must learn to conserve what is left of her bountiful natural resources. But the mental habits engendered by the tradition of cheap, inexhaustible land are still there and will be hard to unlearn, though the American people, always courageous and adaptable, have given a stimulating lead to the rest of the world by their prompt and persistent efforts to do so, as we shall see in the next chapter.

The dismal history of European mismanagement of the virgin soils of North America in the early days has been repeated again and again, with variations, in other continents, in Africa and Australia in particular. Asia already has her own problems, in trying to feed 300,000,000 people in India and another 400,000,000 in China on soil which is already in many parts impoverished and eroded to a horrifying extent. In Asia, in fact, the problem of adjusting the relations between man and his physical environment has already got hopelessly out of hand, because of the astronomical increase in the numbers of Asiatics during the last century or so. When men get too numerous for nature to tolerate, she can and does use the weapon of famine, against which in the final resort man is defenceless. This weapon she has long been wielding with murderous effect in the more densely crowded countries of Asia.

In Africa, where soil erosion is again only too prevalent, its

causes are rooted deep, as they are elsewhere, in the social traditions of the people and the problem is made even more intractable by the clash of interests between the various races that occupy the continent, more particularly between the African and the European. Shifting agriculture is one cause of soil deterioration, but only in places. Over-grazing by cattle is another, mainly in the East and South; the tropical areas at present under the domination of the tsetse fly have hitherto escaped this particular hazard, though they sometimes suffer from the first. Many cattle-keeping Africans regard their cattle as a measure of wealth, and the more cattle a man keeps the higher is his social standing. It does not matter if the cattle are half-starved, diseased, sterile and useless beasts; they are still cattle and as such are to be prized more on account of numbers than quality. When natives with this particular social tradition are herded into reserves by encroaching white farmers, reserves, too, which are often located on the higher, less easily farmed lands near the headwaters of the rivers, the pasture of the reserves gets badly over-grazed, the sod eventually breaks down and soil erosion begins. Soil erosion near watersheds is particularly disastrous in Africa, because as a continent she is short of water and has few permanently good rivers.

In Australia, soil erosion has followed over-grazing of natural pastures by sheep, all too capably abetted by rabbits. The natural vegetation of Australia and New Zealand evolved in the absence of large flocks of close-grazing animals such as sheep and is consequently not very well adapted to resist their onslaughts, whereas the pastures of the rest of the world evolved side by side with the great flocks of herbivores such as the big game animals of Africa and the buffalo of North America, and so can better withstand the treatment they get from herds of domestic animals. Only on the better, more expensive land in Australia is it worth while to sow introduced grasses. In years of good rainfall the sheep increase rapidly; when, in the capricious Australian climate, the inevitable dry years follow, the sheep—and the rabbits—eat off first the dried-up grass, then the

seedlings of the shrubby evergreen bushes that are so characteristic of the Australian flora and that act as a reserve of fodder, and at last the slow-growing evergreen bushes themselves, so that there are none left to re-seed the land when the wet years return. Nothing is left, and the soil has no further protection, dry as it is and trampled to dust by a million tiny hooves, against the sweep of the parching winds. Land in much of Australia is too poor and too cheap to be worth the cost of fencing, and only by fencing it against both farm animals and rabbits, and by deliberate and expensive re-seeding, could it be got back into condition. Meanwhile, with relentless logic the desert spreads.

This is but a bare and very superficial sketch of the processes and some of the causes of soil erosion in a few parts of the world where it is now especially bad. It may be noticed in passing, however, as a particularly ominous sign, that those parts of the world include some of the ones from which we in crowded Europe still draw our cheap imported foods, wheat, meat, animal and vegetable fats, and our raw materials such as wool and cotton. Perhaps it is worth pointing out, too, that we do not send back in payment equivalent quantities of humus and minerals, nor do we pay a price that would allow the farmers of those countries to procure these things for themselves and so prevent their soils from deteriorating; we send them machinery to let them work the land more easily and carry away its produce more expeditiously. The bare outlines of the sketch I have given can be filled in from any of the books on soil erosion now appearing from the world's presses in an ever-swelling stream, in particular from the classical work by Jacks and Whyte, *The Rape of the Earth*, Paul B. Sears' *Deserts on the March*, Fairfield Osborn's *Our Plundered Planet*, and Vogt's *Road to Survival*. It is a grim picture that these books paint. But in my own bald sketch I hope that I have said enough to show that the causes of soil erosion are not just biological but social too, and lie not simply in wasteful and thoughtless land use but also in human traditions, desires and beliefs. Soil erosion in the newer conti-

nents has its roots deep in the soil of Europe and deeper yet in human nature. In India some of its causes are to be found in the Hindu's age-old, ineradicable veneration for the cow, and indeed for all life; in China ancestor-worship with its unavoidable correlative of a high birth rate helps to complicate the problem, as does the Catholic attitude to birth control in much of Europe, or the negro's contempt for childless women in Africa and the West Indies. So the tale goes on. It is going to take us every vestige of the wisdom and courage and foresight and self-control that we have at call to extricate the human race from the morass in which it is rapidly being engulfed, because we have not yet learnt to treat nature with the same forbearance and respect that we exact in our dealings with each other.

The problem is enormous, subtle, and infinitely varied and complex; like most geographical problems, it is not susceptible of solution on purely scientific lines. We know what ought to be done to save the soil: science can tell us. But who can tell us how to change the religious beliefs of the Indian or Chinese peasant?—how to persuade the American or Australian farmer that the future of humanity is of greater concern than his children's schooling or his wife's new refrigerator?—how to straighten out the tangle of racial antagonisms that prevents a direct attack on the task of rehabilitating the soil of South Africa? How is Europe to be fed if millions of acres of food-exporting land in the new countries are retired from cultivation until their soils are regenerated? How, in any case, is that land to be given the chance to recuperate under the systems of land ownership and finance at present operating in those countries, when it is the only means of livelihood of the farmers that work it? And while we seek a solution to these problems—and we need to find one very soon—the soil we have greedily misused to feed our swelling numbers, deteriorates without haste but without pause, and the ruin spreads, as the august laws of nature operate unperturbed alike on the dead and the living, on the rocks and the soil, on plants and animals and on man.

In the next chapter we shall study the progress hitherto made towards finding a solution to this, the most important problem now facing mankind.

CHAPTER X

SOIL CONSERVATION

IT was on May 12, 1934, that the dust clouds from the Great Plains first darkened the skies of the eastern cities of the United States, and in 1935 the American Soil Conservation Service was born. It may well be in the future that that date will be remembered when the dates of the Battle of Britain and of the victory of Stalingrad have long been forgotten. Perhaps that event may at last mark the turning point in the long history of man's ruthless exploitation of earth's riches for his own ends. The Soil Conservation Service has begun to show us the way; we know what ought to be done, now, and we know a little of how to do it, thanks to the pioneering efforts of the Soil Conservation Service since its inauguration.

Perhaps the biggest benefit that we have to thank it for is that it has shown us how a democratic people may be educated to appreciate the damage that is being done to their soils and their wild life by traditional methods of exploitation: America is certainly very much more soil- and wild-life-conscious than she was in 1935. Her education along these lines has still a very long way to go, as is shown by the recent efforts in Congress of certain groups of interested parties to make it possible for themselves to exploit some of her few remaining national reserves of natural timber and grassland, but it has been well begun, and this difficult achievement must be largely placed to the credit of the Soil Conservation Service. Now, having worked out techniques which will at least make a start on the process of stabilising and improving eroding soils, it is providing experts and trained technicians to tackle the soil problems of other countries so that the work begun in the United States may be extended to those also.

There is, however, no ground whatever for complacency; the

dangers that beset us are as real and as pressing as ever, as one fact, recently given in *The Economist*, will show. Since its inauguration the Soil Conservation Service, helped by the revulsion of popular feeling that followed the Dust Bowl tragedy of the later 1930's, has contrived, by hard and difficult work accompanied by heavy expenditure, to retire from cultivation in the Dust Bowl half a million acres of land which should never have been ploughed. But there has recently been a cycle of good, wet years in the region, and farm prices have been extremely high owing to the war, so that at the same time no less than a million acres of new land have been brought under the plough. What is to happen when the inevitable cycle of dry years returns? Education has evidently still a very long way to go.

As I said at the end of the last chapter, it is much easier to know what we ought to do to save the soil, than to get it done. Getting it done, if the ways to do it run counter to deeply rooted traditions, beliefs or desires, is often a very difficult process indeed. Moreover, it must generally be preceded in a democracy by a very large measure of popular education, which is a business so slow that one is inclined to wonder whether, in view of the urgency of the problem, we can really afford the time to teach people the right attitude to the soil before embarking on the urgent task of saving what is left of it. A recent calculation published by the United States Soil Service, quoted by Fairfield Osborn, states that in that country, the richest and most productive in the world, the country that is going to ensure enough food for the undernourished millions in the rest of the world, "soil losses by erosion from all lands in the United States total 5,400,000,000 tons annually. From farm lands alone, the annual loss is about 3,000,000,000 tons, enough to fill a freight train which would girdle the globe 18 times. . . . In a normal production year, erosion by wind and water removes 21 times as much plant food from the soil as is removed in the crops sold off this land." How long can this go on? Even the rich land of the United States will not long survive such a drain on its very life-blood and substance. Yet in other countries all over the

world the position is every bit as bad, and even less progress has been made there towards checking the enormous losses of soil that occur every year.

Then, too, the expense of embarking on large projects of soil conservation is often very heavy and usually, in a democracy, the money has to be voted for the purpose by the elected representatives of the people. But in many of the lands most directly concerned—Australia, South Africa and the United States, for example—the majority of voters live in the towns, and it is very hard indeed to make town dwellers realise the appalling urgency of what is to them an abstract problem. Is it likely that the representatives of town and city populations would encourage the government to spend millions of the public's money on schemes for reafforestation or river control, or on loans to farmers, when those millions once spent are likely to show no return for decades, and perhaps no direct return at all?—although they are likely to have an immediate and adverse effect on town-dwellers' purses by sending up prices, for the time being at any rate. In the short view cheap food is of far more importance to town dwellers than anything else the land can provide; and it is not only town dwellers that are reluctant, in these doubtful days, to sink capital in far-sighted schemes whose full results they may never see. Would *you*, if you were an American or Australian farmer, be prepared to sink thousands of pounds of your hard-earned savings in replanning your farm and altering your system of farming, when you knew that you were likely to get no return whatever on much of your money for many years and would meanwhile not even have your usual produce to sell?—when you had no secure markets for the new crops and live-stock you might raise?—and when, above all, you had no security of tenure of the land for your sons and their sons, so that your children and grandchildren might reap where you had sown? We do not build for the future like that in these turbulent days: Death Duties see to it that we do not; and we like a return on our money while we have got it. Soil conservation requires expense, often enormous expense, without any

immediate return. We have now been living on the soil's capital for centuries, and the reckoning has at last come, because there are no new lands left to exploit; but it is unwelcome as reckonings always are. Yet, unless we are prepared to meet it, by lavish expenditure of the money and labour we have hitherto grudged, the prospects for much of the human race in the next few decades are dismal indeed.

The methods of soil conservation are various, and the ones used depend to a great extent on local conditions and the local reasons for deterioration of the soil. The United States Soil Service classifies land into eight grades, according to inherent fertility, slope, and general relationships and conditions, stipulating for each grade what is the best and most profitable use to which that land may be put without drawing on its capital of fertility. Thus the richest lands in Grade 1, flat so that they are not easily eroded by water and with a climate moist enough to spare them erosion by wind, are cultivable year in, year out, by employing ordinary good farming practices without any special conservation measures. Other soils, thinner or on slopes, must be treated with more care, until with the poorer grades of land the most satisfactory uses may be to plant them down to trees, or leave them as wild-life reserves, or seed them to grassland with carefully-controlled grazing. This preliminary survey and classification of land is necessary before any comprehensive schemes for soil conservation can be adopted.

Whatever more elaborate methods of land conservation may be needed, they must always go hand in hand with good farming, farming that does not impoverish the soil by taking crop after crop from it without returning the crop residues for humus and replacing the extracted minerals. Good conservation farming is good mixed farming, using well-proven rotations of crops and if possible keeping livestock to tread the straw of the cereal crops into manure or to eat down the grass of the sown leys. Of the more expensive methods of conserving wasting soil even the best will fail, if they are not accompanied by good sound farming practice. As a first step in soil recovery, mixed farming

with proper rotations should replace one-crop farming; animals should be used to supplement artificial fertilisers with good manure, which provides the humus the soil lacks; the land should, in the old-fashioned phrase, be put into good heart.

Before this, however—and this is where soil conservation is such a particularly fascinating subject for the geographer, who is trained to look at all the issues involved in a question—the problems of every local area have to be looked at as part of a whole, in relation to the relief, drainage and climate of the whole region as well as in relation to the population, its numbers, distribution, ways of earning a living, habits, traditions, degree of education, health, and a thousand other things that will all affect and be affected by its relation to the soil. Soil conservation planning, in fact, should be biogeography in action, a direct effort to put human communities into the best and most harmonious possible relationship with the whole of their environment, physical, biological and social. For, to give a more concrete example, it is no use persuading a farmer in the middle reaches of a river valley to use conservation methods to save the soil of his own farm from further deterioration if at the same time a timber company fells the woods round the headwaters of the stream, and other farmers above him on the slopes go on recklessly exploiting their land, so that after every heavy rain the water-meadows of our hypothetical farmer are drowned in muddy water and his best fields are buried in silt. Conservation of soil is so intimately bound up with the physical form of the landscape, in particular with the drainage, that to make conservation work properly in any one place it must be undertaken simultaneously over the whole of a drainage basin. Only so can one be sure that all the labour and capital sunk in the necessary works will not be thrown away by the thoughtless actions of individuals who try to make profit for themselves out of their neighbours' efforts. It is the indissoluble tie between land use and land form that has given rise to so much trouble in the United States where, in the days when men spoke grandly of "conquering the wilderness" and "mastering the soil," the

land was laid out in straight-edged chunks convenient for administration without any regard at all for the despised and "subdued" natural features such as the tiresomely irregular water-courses and hill-slopes.

"We squared the country for liberty, laying it off
With the posts plumb on the section lines and the fences
Following due west from the creeks of Kentucky
To the counties bigger than Delaware: christened for congressmen. . . ."

Today the convenient administrative units, that ignored the natural shape of the land, are a real hindrance to the process of replanning land use in accordance with natural laws, which are the only ones that will keep and hold the soil. This difficulty was first encountered on the grand scale by the Tennessee Valley Authority, since the Tennessee valley included portions of several different States which could not be treated individually if, as was essential, the land use of the valley had to be replanned as a whole. Even so, the T.V.A. scheme did not fully envisage the results that might attend failure to insist on proper soil-conservation farming—even by compulsion if no other means would serve—in every single farm in the whole of the valley; in the event, erosion on the farms that have failed to adopt the new methods may undermine the success of the scheme as a whole, since uncontrolled erosion even on a single farm is a running sore which spreads and spreads so long as it remains untreated, gradually engulfing formerly healthy tissue.

The first thing, then, in rehabilitating wasting soil, is to plan as a whole, river valley by river valley, and direct attention first to the river itself and to its tributaries and their tributary gullies. In eroded country the river will be liable to sudden spates and floods after rain, alternating with periods of low water when its bed will be half-dry and choked with sandbanks formed of the silt that it has washed off the higher land and cannot carry when its waters are low. If the river is polluted as well then we shall have:

"The pools sluggish with sewage, choked with tree-trunks:
The stream-beds stinking in the August sunlight."

The first thing, then, to do with the river is to try to even out its flow by raising the low water level and reducing the spates. For this it will probably be necessary to get the trees back on to the higher slopes of the basin, on the land too steep or too bare to cultivate or graze successfully. Here it may be necessary at the start to buy up the farms whose cleared land has caused most of the trouble, resettle the farmers elsewhere and retire the land permanently from cultivation, planting it to forests. In time, if properly managed, as they are in the Swiss Alps, these forests will bring in a steady income from their annual cut of timber, but clearly at the outset such a process requires a heavy capital outlay on which no return can be expected for many years. Moreover, results may not show at once on the rivers, and also before planting it may often be necessary to treat the land by contour terracing (see below) to slow down run-off and keep the water on the soil for the young trees. This too is a very expensive process.

In other parts of the basin quick run-off may result from gullies eating into the farm land. The gullies must also be treated at once, in one or other of a great variety of ways. Small gullies can be filled with brush and soil, or obliterated by bulldozers in the process of terracing the farm lands. Others may have to be blocked by check dams built across them at frequent intervals, to hold water for stock and to catch silt which helps to fill the gully. Their sides may be planted with quick-growing, soil-binding perennials, grasses, shrubs and trees. Since the gullies may eventually find a use as cover for wild animals and birds in the final plan, plants which provide food for the wild animals that it is desired to encourage are often a good choice for this purpose.

To begin with also, each individual farm may need replanning to a new layout designed to avoid the mistakes often made in placing buildings and roads on a farm without any thought of geographical factors. Roads, if badly placed in relation to slopes, are often a prolific source of gullies, because they may concentrate the run-off water from rain and pour it into the

fields at one or two places, where its erosive power is much enhanced. Fields may need refencing, to keep stock off land unsuited to grazing, or out of patches of woodland newly planted to accord with the general plan. Besides this, each individual farmer may become involved in very heavy expenditure, with no likelihood of immediate return, for gully control and other conservation operations such as contour terracing. The whole of his farming practice may need reorganisation; he may need new buildings, new machinery, and new water supplies for stock, before he can turn over completely to good conservation farming. But this money has got to be spent if the soil is to be saved.

Reafforestation and gully treatment alone are often enough to regenerate springs that had dried up when the forests were cut; the springs will raise the low-water level of the river and reduce the effects of pollution, which are most serious when the water is low. Clearly, while other concerted efforts are being made to regenerate the river and aid its recovery from the evils man has brought upon it, the problem of pollution should be tackled too. Again, this costs money, and the only return at first is in the form of improved amenities, and a purer water supply for farms, towns and factories lower down the stream; without legislation it is hard to induce mill-owners to embark on expensive projects whose main benefits will accrue to others, not to themselves.

As the rivers are being gradually brought back into health by headstream and gully treatment the farm lands must be treated as well, to reduce the rapidity of run-off after rain, stop the soil from washing down the slopes, and hold the water on the land so that it can sink in to feed the crops and raise the water table. Where land is fairly level and the soil has been but little wasted, change of farming practice may be enough to save it, but if sheet or gully erosion has started, or if the land slopes much so that water runs off easily and quickly, more than this is needed.

Contour ploughing, one of the most fundamental principles adopted to protect the soil against water erosion, is seldom if ever seen in this country, where we are more apt to want to get

rid of rainwater than to want to keep it on the land. Our familiar plough furrows run up and down hill, straight across country, and so gentle is our rain and so absorbent our topsoil that water seldom rushes down them in torrents, even after heavy showers. But in many of the drier parts of the world this way of running furrows, that we in our climate take for granted, has been disastrous, especially once land has begun to erode and its capacity for soaking up water has begun to diminish. In contour ploughing the furrows are run horizontally round the slopes, so that the water falling on them is caught and cannot run off swiftly downhill. Contour-ploughed land looks odd to our eyes, yet has a bizarre beauty of its own. It is a curious expression of the control of man by geography, a translation into landscape of the aphorism that you cannot carry on square farming on a round earth. It is a form of poetic justice, too, that in America, the country of square sections and quarter-sections, contour ploughing in which not a single line is ever dead straight has first come to be used on a large scale. It seems, though, a very simple and obvious adaptation to the physical environment of countries with long dry spells or inordinately heavy rainstorms; it throws an odd light on man's vaunted brain to consider that he has taken six or eight thousand years to think of it. Now a South African conservation slogan runs: "Plough on the contour, plant on the contour, irrigate on the contour, if you want your children to inherit your farm."

In justice to our ancestors, the more radical invention of contour terracing is almost as old as farming, and too well known to need much description. It is used for vineyards in much of Europe, where the vines, near the northern limit of commercial growing, huddle below the south-facing slopes of the valleys and in the sunnier corners of the mountains. All over the Mediterranean basin vineyards, olive and citrus orchards, and small fields—gardens, almost—of cereals and vegetables are found on terraces, and where the terraces are well maintained the soil is safe. But terraces in Europe are nothing to those of the rice country of the Far East, where they produce a unique

and fascinating landscape; the hillsides rise from the lowlands in broad curved steps, their treads carpeted in colours ranging from brilliant blue when the flood water lies on them and reflects the sky, through the jewel-green of the young rice, to the yellows and browns of harvest. Terraces of almost equal elaboration were formerly used by the Incas of Peru and other agricultural Indian peoples of America, but they were allowed to fall into hopeless disrepair after the Spanish conquest; here again the European has helped on the work of destroying the soil of the newer continents.

Terraces, like most of these conservation measures, are very costly to construct and to keep in repair, though it is often forgotten that the same can be said of field drainage in this country, an operation the expense of which all farmers take for granted and budget for. In modern times a cheaper substitute is often made by machinery, if the slope of the land is not too great. Deep grooves are run along and round the hillsides; the broad surface on the tread of the step thus formed has a less slope than the average slope of the hillside and so is less vulnerable to rain wash. If carefully engineered and then well covered with soil-holding plants these may be extremely effective, and they can be used on pastures and in orchards as well as for arable land.

Whatever contouring devices be adopted—contour ploughing, earth terraces made by machinery, or stone-faced terraces—they must be kept in good condition and not allowed to deteriorate or the hillside will soon become again nearly as vulnerable to erosion as it was before. The ends of terraces or grooves, where the water runs off, must be watched particularly carefully, lest they erode back and undo all the good done by the expensive and elaborate construction.

Strip cropping is simply the practice of growing crops of various kinds, not in huge pure stands of a single kind of plant regardless of the run of the slopes, but in long, fairly narrow strips running, like the furrows and the terraces, horizontally round the slopes. Strips of a clean-tilled crop such as maize or

cotton alternate with strips of soil-binding crops, particularly grasses and clovers which at the same time feed the soil with humus and nitrogen. Such soil-binding strips are wide enough to hold the soil firmly against any wash of water or soil coming down from the clean-tilled crop strip above. Our own familiar hedges, where they run horizontally across slopes, act on the same principle. Their use in holding the soil up on the slopes is plain enough; you have only to compare the height of the earth on the uphill and downhill sides of such a hedge to see the valuable work it does.

Strip cropping is clearly a practice which fits in well with crop rotations but cannot be used in one-crop farming systems. It also works in well with contour ploughing and terracing. Thus all the conservation practices tend to reinforce each other, and a combination of several of them may show remarkable results in a short time in improved yields and quality of crops and livestock on the farms. Surely we may learn from this the value of adapting our own methods to work in with natural laws; once we begin to conserve the soil instead of wasting it by greedy and thoughtless usage the process becomes almost self-perpetuating, though so long as we continue to take out of the soil more food for man, whether plant or animal, than could be supplied by purely natural growth, so long must we return to the soil correspondingly greater amounts of plant and soil foods than would be returned to it by natural methods. Once conservation practices are well established and regularly carried out the ground may well yield a bigger total of food than it did before, even though less of the total area is being called upon to do the actual growing of the crops and more of it may be under trees or grass or used as wild-life reserves, protective shrub plantations for river banks and so on. The properly-planned, properly-worked land that is conserving, feeding and building up its soil is, in fact, the nearest that we have yet come to the perfect adaptation of man to his physical environment. A landscape managed on these lines should show a perfectly harmonious mixture of arable land, grass land, woodland and orchard; clear

streams of pure water, fresh with green plants, caddis worms, insects and fish; wild birds in abundance to keep down insect pests of the crops, and larger birds of prey to keep rats and mice and rabbits within bounds. The breeding sites and foraging grounds of animals are respected, so that they can thrive and hold the balance of numbers even, with no one species increasing so fast as to become a pest. Such a landscape—there are some like it yet to be seen in this country, though they get fewer month by month—is beautiful to the eye and satisfying to the mind; it is peaceful and harmonious, breeding contented people well fed with good food. As an ideal for all countries it is surely something worth striving for, something that would, if it could be realised, heal most of our present discontents and resolve many of our problems. But in the light of what I have already said of the difficulties confronting anyone who tries to initiate soil conservation measures in most democratic countries at the present day, we may well wonder whether this ideal is any easier of attainment than the Kingdom of God upon earth.

This is, in fact, where the totalitarian states have a really colossal advantage over the democracies, and in a matter of such immense and vital importance it is difficult to over-estimate the value of such an advantage. In the U.S.S.R., where there is no individual ownership of land, planning for soil conservation can be done easily, and the plans can be carried out in their entirety. The soil problems of the U.S.S.R. are in many ways similar to those of the United States: each possesses a vast area of flat or rolling plains with a continental climate; each has a great and growing industrial population, and each relies largely on soils of the black-earth type for its heaviest cereal harvests. But though the U.S.S.R. has more desert, more almost useless tundra land, and a more extreme climate, she has a totalitarian economy, and can initiate and carry out schemes on a continental scale, with the certainty that everyone concerned will co-operate; she will have no difficulty over compensating evicted farmers, or persuading unwilling farmers to sink in the land money from which they will get no immediate return. The land is the

State's. To expend capital on improving it is to make the very best conceivable use of that capital, and in the life of a State ten years or a hundred years are of no significance; it is as easy to plan for the far distant future as for next year. So Russia is embarking on immense schemes to rehabilitate her soil, by reafforesting parts of the treeless steppes so as to make them more productive, by deflecting some of the great rivers into new courses and using them to irrigate lands now too dry for crops, and by putting into practice on an enormous scale some of the soil conservation methods mentioned earlier in this chapter. If she succeeds in this great attempt, even with all the advantages on her side, she will still have achieved a victory immensely more important to the human race than that of Stalingrad; she will be the first great country of modern times to find a working solution to the problem of man's relations with the soil, the biggest of all the problems at present facing mankind on this planet.

What of the rest of the world, particularly the great democracies? They have many and great handicaps in their fight to re-establish themselves in a right relationship to the soil. The heaviest of these is their burdensome weight of ever-increasing population, already too great to be fed well from the cultivable land of the earth. The gathering momentum of population increase in so many countries—Russia suffers here, even if she has other advantages—means that there is very little time for us to put our house in order before nature will do it for us, by famine; there is malnutrition over much of the world already. In spite of this, most countries, for a variety of reasons, political, economic and religious, actively encourage their populations to grow faster, mainly for fear of what may happen, in the way of political conquest or economic distress, if they begin to decline. We ourselves are guilty of this particular form of shortsightedness.

Another handicap from which the democracies mostly suffer is that resulting from individual ownership of land, combined with the desire of individual owners to gain a profit from their

ownership. The profit motive has probably been the biggest single factor in bringing about the present world soil crisis. There is no doubt, unpalatable as such a truth may be to most of us, that a true balance between man and the soil would be rendered immensely easier to attain by State ownership of all land, or by active and intelligent State control of individual land use in accordance with a well-thought-out, far-sighted scheme worked out for whole regions at a time. There is a fruitful field here for international co-operation. But there must be really constructive planning; our present myopic Town and Country Planning Act is useless for the purpose in its present form, since it repeats the mistake made in America of working by administrative rather than geographical units, and it does not achieve a satisfactory balance between local and wider interests. Planning, moreover, in a country such as ours, fed largely by imported foods, is going to be a much more critical process, requiring far clearer vision and much more political acuity than our planners have yet shown, when we have to feed more and more of our people from our own land, as our overseas suppliers one by one set about conserving their own soil resources and cutting down their exports overseas. We have already had some foretaste of what we may come to in the reduction of Argentina's meat exports, but meat is merely a luxury food; the real pinch would come if Canada ceased to export wheat to us, or New Zealand butter and cheese. We in this island could probably starve more easily than the people of any other country in the world, because we have let our numbers grow so criminally large in comparison with the land we possess and the possible amount of food we could grow.

Numbers of people, systems of land tenure, and the desire for profit: these are the villains of the piece in the big democracies. Against them we can only array the weapon of public opinion, vastly powerful when well used, but often stupid, misdirected, and inordinately slow in moving into action so that its edge is apt to be blunted and its power wasted before it can make its effects felt. To arouse public opinion, to educate it to know the

true state of things so that it may press for rapid, efficient action in finding a solution to our problems, this is your task when you have taught yourself Biogeography.

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CHAPTER XI

PESTS AND DISEASES

IN Chapter V we saw that every animal is obliged to use other plants or animals as food, and that there is a systematic relationship, the Pyramid of Numbers, between species that eat and those that are eaten, so that the species on the summit of the pyramid can only increase in numbers to the extent allowed by the numbers of the species below it in the pyramid. We have devoted several chapters to man's efforts to expand the base of his own pyramid by growing crops and raising domestic animals for his food instead of relying on wild plants and wild fish and game. We saw how successfully he has achieved his aim, since there are now about 2,000 million men on earth instead of the mere 20 million which is all the earth could feed if men were still hunters instead of farmers. Man has not achieved this spectacular rise in numbers, however, without creating a host of new problems for himself, some of which, as we have seen, are very urgently in need of solution if we are not to suffer from world-wide famine in the near future. These are the problems arising from man's treatment of the soil which helps him to grow his food. The problems of exhaustion of fertility and of soil erosion are at bottom problems of a faulty relationship between man and the soil, particularly between man and "the vast unpaid labour force," the myriads of minute animals and plants that live in the soil and help to make and keep its fertility.

But as he has increased in numbers man has also changed many other relationships between himself and the living things around him. He has exterminated a horrifying number of animals and some plants, and has reduced very many more to the point of extinction. The Passenger Pigeon, which in the early days of settlement in North America used annually to darken the sky with millions of flighting birds, the Dodo, the Great Auk

and Steller's Sea-Cow, are among the strange and interesting animals that man has wantonly destroyed. Even more, he has pushed back and gravely reduced in numbers hundreds of other plant and animal species, in order to make room for his crops and his dwellings; where once western Europe and eastern North America were covered with millions of trees, there are now arable fields and pastures, cities, roads, factories and garden suburbs. Instead of the trees, the plants that grew under them and the animals that lived among them, there are millions of wheat, maize or cabbage plants, and along with this change in the numbers of one set of species goes a corresponding change in the numbers of other species of plants and animals that prefer pastures or fields of wheat to forests.

Man's objective all along has been his own advantage. The plants and animals that thrive in the new environment that he has created by his efforts, however, are the ones that like the same sorts of things that he does. A newly cleared field is not only a good place for young wheat plants to grow in: it also suits very well such plants as thistles, bindweed, poppies, charlock, corn marigold and the hosts of other weeds of cultivation that follow man about so faithfully wherever he tries to till the soil, because they like the new conditions he creates thereby much better than those of the forest that once grew on the same ground. Then, too, a field of ripe wheat presents a wonderful spread of food for armies of rabbits, mice, sparrows and small finches, which live in open country or in stackyards in numbers that no forest would support. The grain once harvested and stacked, or stored in barns or warehouses, it feeds rats and mice, which increase at a fantastic speed, since they are protected from the foxes, owls, weasels and other predators that keep down their numbers under less artificial conditions. As the owls' nesting trees are cut down, and the rough spinneys and wild country that served as a retreat for the carnivorous animals during the breeding season are swept away to make room for crops, the natural enemies of the rats and mice disappear, and man is obliged to replace them by a new set that can live in the

new conditions, domestic cats and dogs; he even has to go into the predator business himself with traps and guns and poison. A man who sets a mouse-trap is doing the job that nature designed for an owl or a weasel.

What man has done, in fact, is to broaden the bases of a lot of other animals' food pyramids while widening his own, the pyramids of other animals that live, like him, on a mixed diet with a lot of cereals, and are unspecialised in structure and adaptable in their habits. At the same time he has often knocked off the upper storeys of their pyramids, so that the species in the middle tiers of the pyramid are not only able to increase in numbers almost unchecked by their larger natural enemies, but are positively invited to do so by the banquet of food that man has inadvertently spread before them.

The species that can profit by these conditions are mostly only too familiar to us. They are the animal pests of cultivated plants—black fly on broad beans, white butterflies on cabbages, monkeys in the sugar-cane, Colorado beetles in the potatoes, boll weevils in the cotton, and a myriad more—and the animal pests and vermin that infest grainfields, warehouses, store-rooms and our own kitchens and larders—rats, mice, cockroaches, clothes-moths, meal worms, house flies, sparrows, and the host of their unlovable associates. But these are all fairly large and easily visible, and very few in numbers compared with the plants that thrive in much the same conditions; these include the weeds, "plants in the wrong place," and worse still the microscopic plants such as fungi, causing blights, mildews, moulds, bunts, smuts, rusts and other diseases of cultivated plants, and the even smaller but just as virulent bacteria and viruses producing an equally long and depressing list of diseases. Others of these pestilential organisms produce diseases in livestock, and some in man himself. All tend to increase more rapidly, and their increase becomes more difficult to check, as man, striving to increase his own food supply and his own numbers, obligingly increases their food supply too. This increase in pests and disease-producing organisms, the undesirable hangers-on of our

advancing civilisation, is an unavoidable consequence of man's own actions, as he steadily alters the conditions of soil, vegetation and so on to suit himself and his crops in his deliberate and fairly successful attempts to make himself the dominant living species in the world.

To improve this unfortunate state of affairs is not at all easy. If we reduce the numbers of one pest, with the many excellent scientific weapons we have at our command, but do not simultaneously alter the conditions that encouraged that pest to thrive, the place that it filled in the complex interlocking society of animals and plants which forms the whole environment will at once be taken by another species capable of adapting itself to fill that particular role in that society. The new species is often harder to get rid of than the one it replaces. In Barbados, where there are very few hawks or owls, no snakes, and no large carnivorous animals except cats and dogs, the rats brought in unintentionally by early settlers increased so much and became such a pest that the Asiatic mongoose was introduced in hopes that it would exterminate the rats. At first the mongoose tipped the balance of numbers against the rats and, from man's point of view, all went well; but as the numbers of rats declined and that of mongooses rose, the balance swung back; the mongooses, with fewer rats to eat, took to eating eggs and fowls as the rats had done, but with the difference that whereas rats could be killed by cats mongooses could not, and they proved even bolder and more successful thieves than the rats. Now the two species live side by side, sharing between themselves the eggs, birds, stored food and so forth that used to have to provide for the rats only; so the trouble is worse than it was before the mongoose was introduced. This example is but one of thousands of similar ones, in which destruction of one pest has merely led to its place being taken by another, even more difficult to deal with than the first. The parable of the Seven Other Devils has a direct application to plant and animal ecology.

A lot of the trouble we have brought upon ourselves gratis, by moving plants and animals about from one part of the world

to another with an eye solely to our own convenience. In doing so, we upset one group of plants and animals already living together in a closely-integrated society in which the numbers of all the constituent species are delicately balanced, by introducing other species adapted to different conditions, species to which also the existing plants and animals are not already adapted. For instance, the native grasses of New Zealand evolved in the absence of any large grazing animals such as sheep, and are less palatable to sheep and more easily killed off by them than the grasses of our own upland pastures, which have evolved along with sheep and other grazing beasts. The common weeds of cultivation originated very largely in the North Temperate Zone, where extremely active competition has brought to the fore those plants best fitted to thrive under the conditions of modern agriculture; these, when introduced into new countries along with that agriculture, are generally more successful than the plants that have evolved to suit the undisturbed natural conditions of that country. So the common European bracken and bramble have become serious pests in New Zealand, as the bramble and the foxglove have in Southern Chile; the creeping thistle causes even more trouble in Canada than it does in this country, and so on. Wherever man goes he takes his weeds with him, generally by accident, along with the crops that he introduces into new countries in order to grow there the kinds of foods or raw materials that he wants or is used to.

Sometimes, in moving plants about the world in this way, we have been lucky. When Henry Wickham took seeds of the Pará rubber tree, *Hevea braziliensis*, from the Amazon to Kew, to become the parents of the vast rubber plantations of the Far East, he left behind in Brazil all the natural pests and diseases of rubber that could not be carried on the seed, in particular the South American leaf-blight. The Far Eastern plantations flourished in its absence, but the blight has proved a serious obstacle in the way of re-introducing the improved strains of Far Eastern rubber to plantations in the New World.

Far more often we have been unlucky, and many of the worst

headaches arising from introduced pests man has deliberately given himself. "No occurrence in the history of Australia," says the *Australian Encyclopædia*, "has so profoundly affected her economic development as the introduction of the rabbit." This may be an exaggeration, but nevertheless it is estimated that the stock-carrying capacity of Australia has been reduced by about a quarter solely by rabbits, and they cost the Commonwealth millions of pounds annually in loss of pasture and attempts at control. The part they play in destroying Australia's soils has already been mentioned on page 150. Yet they were introduced deliberately, and over and over again: rabbits sailed in the First Fleet. Not long after their first introduction into Victoria a man who shot a rabbit, the property of John Robertson of Glen Alvie, was fined £10; a few years later the same John Robertson spent £5,000 in trying unsuccessfully to stamp out the wild progeny of his rabbits. The prickly pear cactus, introduced into Australia both as a curiosity and as a possible reserve fodder for stock in dry seasons, at its greatest extent covered and rendered completely useless 60 million acres of land, more than twice as great an area as that under crops in the whole of Australia; on half at least of this area it was said to grow "so thickly that a dog could not bark in it." During the last twenty years it has been reduced to manageable proportions by judiciously introducing, from its home in America, some of its proper natural enemies, of which it had none in Australia.

These two are more striking instances than some, but there are hundreds more of the same kind to be found all over the world, and the total cost to man of his inept attempts to grow more of the kinds of plants and animals that are useful to him, and less of those that are not, is beyond computation. It is estimated, for instance, that over 98 per cent of the diseases of crop plants in New Zealand have come into the country from overseas, brought in on seeds, bulbs, or living plants, or in timber, smoking tobacco and other plant products introduced in the first place with an eye to profit. Now it costs a commercial fruit grower 1s. 6d. a tree to combat diseases in his

orchard; diseases affecting turnips grown for winter feed are estimated to reduce the stock-carrying capacity of the South Island by one-third; of the "Maori peach," which in the days of the early settlers grew wild, free from disease, so thickly that the rivers yearly carried to the sea thousands of luscious ripe peaches from the trees on their banks, none survives today, owing to the spread of introduced diseases.

So the dismal story goes on. Most advanced countries now have strict legislation controlling the introduction of plants and animals for fear of bringing in with them disastrous new pests or diseases. Our own quarantine regulations for dogs serve to keep our islands free from rabies, but our equally strict quarantine regulations for plants are less well known but probably much more valuable. In the United States, if you wish to bring in seeds of any foreign plant, they are taken at once to a government quarantine station, germinated there, and the plants grown to maturity in special insect-proof glass-houses, and not until the seed set by those plants has produced a second generation of mature plants is the seed set by the second generation released for distribution. Parts of introduced plants have to be budded or grafted to another stock, grown to maturity, and budded or grafted again, so that none of the actual plant specimen introduced survives. Even so, pests come in through the ring-fence of quarantine legislation, by smuggling, by inadvertence, or by pure accident: white butterflies, now a pest in New Zealand, arrived only in 1930 on some cabbages which drifted ashore in Napier harbour when thrown overboard from a ship's galley. And even had United States quarantine regulations existed when first the cotton boll weevil came up from Mexico, it is doubtful whether the weevil would have taken much notice of them.

Man has helped in yet another way the spread of these diseases and pests which take so large a share of the crops he intends for himself. He grows these crops, as a rule, in "pure stands," all of one kind of plant, so that it is easy for a parasite to spread from one host plant to another of the same species. In most parts of the world the natural vegetation is made up of a mixture

of species, though this is not universally true: in the forests of Arctic Siberia and Canada hundreds of square miles of country may carry little besides one or two species of spruce, larch or pine. But a wheat field or a coffee plantation offers ideal conditions for a pest to spread. The devastating Phylloxera, a plant louse living on vine roots, which ravaged the vineyards of Europe from 1865 onwards, "advanced through the vineyards in lines parallel with the first rows of vines attacked," finding no hindrance in its spread from the roots of one vine to those of a near neighbour. The rate of spread of the spores of wheat Rust fungi, from the barberry bushes on which the fungus lives over the winter before attacking the wheat in spring, has been measured: in one instance, by May 26th all the wheat was rusted for 100 feet to leeward of an infected barberry bush; the fungus on the infected wheat produced spores which infected more wheat, and by June 6th the rust had spread to one and a half miles, by June 17th to four miles, and by harvest time ten miles, from its starting point. "The spores from the rusted barberry bushes started the Rust over the wheat much as sparks from locomotives start prairie fires." (Large: *Advance of the Fungi.*)

In a classic investigation of the spread of the disastrous leaf disease of coffee in Ceylon, *Hemileia vastatrix*, which wiped out the big coffee plantations in Ceylon after 1869, Marshall Ward pointed out that the swift spread of the fungus by its spores, carried on the monsoon winds first one way, then back again, was due to substitution of great pure stands of the host plant for the mixed natural forest, in which the fungus had hitherto lived comparatively harmlessly on the scattered wild coffee trees. To combat plant diseases which spread like this, crops must be rotated, or, where this is impossible as with tree crops, they are better dispersed or alternated with other crops instead of being planted closely in pure stands. Varied cropping of this kind has many disadvantages from the purely economic standpoint, but from the biological standpoint it is not only a precaution against the spread of pests but is, as we have seen, also a help in conserving soil. When crops are rotated suitably the pests of each

have no longer a continuous cover of their host plant on which to live, and with a well-chosen rotation cannot survive long enough in the form of spores, eggs, or other resistant bodies to reinfect the crop when planted again after the lapse of some years.

Let us look at some of the results produced by the spread of some of these crop parasites. The ghastly Irish Potato Famine of 1846–47 was the work of a small fungus, *Phytophthora infestans*, which came in from America, the original home of the wild potato, on some infected tubers brought to Europe. It found the unbroken expanses of susceptible cultivated varieties of potatoes in the Irish fields exactly to its liking, and in the very wet, cool summers of 1846 and 1847 it spread with horrifying rapidity, turning the growing plants in the fields into blackened pulp and even infecting the tubers so that they rotted in store. So disastrous was the loss of the potato crop on which the poor Irish peasants relied almost entirely for their year's food, that Ireland lost about 2½ million people as a result, by direct starvation, by disease following on the food shortage, or by emigration to try to escape the horrors of the famine. An indirect result of far-reaching importance was the Repeal of the Corn Laws, an event of deep significance for the economic future of Great Britain, precipitated by the action of the small destructive fungus which had attacked the potato crops.

The Red and Black Rusts of wheat, two forms of the same parasitic fungus, *Puccinia graminis*, have presented one of the most intractable of all problems in plant disease. During the first World War, the whole of the ploughing-up campaign in Great Britain added 25 million bushels of wheat a year to our food supply; at the same time Puccinia was destroying, in two disastrous epidemics in 1916 and 1917, 200 million bushels of wheat each year in the United States and a further 100 million in Canada. This pest can now be controlled, at great expense, by spraying fungicides from the air when an epidemic threatens. The slow and difficult process of building up rust-resistant strains of wheat has also made headway, and in 1940 "Thatcher," a rust-resistant spring wheat, occupied 17½ million acres in the

spring-wheat area of the United States and Canada. Only a year or two before it was introduced the Rust was again destroying over a hundred million bushels of wheat each year. It has in its turn been replaced by other more resistant and more satisfactory strains.

The boll-weevil of the American Cotton Belt has strongly influenced the distribution of cotton growing and the kind of cotton grown, not only in the United States but also in the rest of the world. The weevil grubs live in the young cotton bolls and eat the seeds whose hairy coat is the cotton of commerce. In one growing season the weevil runs through several generations, so that it becomes most serious as a pest when the cotton stands long on the ground. But the best cottons, with the longest and finest hairs, or "staple," take most time to mature on the ground, and so are most susceptible to weevil attacks. This drives growers to plant quick-ripening cottons with shorter coarser fibres, so the weevil not only directly reduces the yield of the cotton fields which it attacks but indirectly lowers the quality of the cotton crop. It has forced many farmers in the Cotton Belt to change over from single-crop cotton-growing to more diversified farming, a change which has also helped to check soil erosion. By its absence, the weevil has also favoured the margins of the Cotton Belt, where the climate is not so good for cotton as in the middle of the Belt, and new cotton growing areas such as Brazil, whose cotton competes for markets with that grown in the United States.

Here, then, are a few out of very many possible examples of pests which by their activities have forced man to change his ways of farming, to find new places in which to grow his crops, and to spend huge amounts of time, energy and money in efforts to control their ravages. Pests of crop plants, their distribution over the world and their tastes in climate, soil and agricultural practice, are factors which must be taken as strictly into account as climatic, economic and historical factors in any study of the geography of crops. The cost of fighting pests in a climate which suits them better than it does their hosts is a factor that often prevents the spread of a crop into new regions. Pests also

limit the return that we can get from a given area under a crop grown by a given system of cultivation; even where ways of controlling the pest are known, there is still an upper limit to the price a farmer can afford to pay and to the labour that he can afford to spare for the processes of protecting his crops from disease, and when this price rises too high he is forced to grow something else.

Meanwhile, the enormous increase in the numbers of insecticides, fungicides and so on that are sold in the shops tells its own tale. A "Spraying Calendar" published in 1948 by a leading commercial firm recommends no less than ten separate spraying operations in order to control pests of apples and of potatoes, for instance. But if we use these sprays and chemicals indiscriminately to control one pest we may find a worse one taking its place, like the mongoose in Barbados, as well as bringing on ourselves a whole Pandora's boxful of unforeseen troubles resulting from upsetting the balance of numbers between different species. It may be possible to improve matters indirectly; instead of using lethal sprays, we may be able to make living conditions less attractive for the pest, for instance by reducing the numbers of its hosts through rotation, diversification, strip cropping and other such devices, and by trying to build up a pattern of agriculture which will in all possible ways favour the host plant against the pest, and will encourage well-grown healthy plants of strains naturally resistant to the pests and diseases likely to attack them. It is a most intricate problem, because so many variables are involved, and we know, when all is said, so very little about these elusive and exasperating organisms that cause all the trouble; there is no easy solution, not at any rate with the present vast world population needing to be fed. The job could be done easily, with the knowledge and techniques we have now at our disposal, if there were fewer of us men in proportion to the other living things on the globe. So we come back again once more to the fact of our unwieldy numbers, that disproportionate increase at the expense of less progressive and intelligent species which lies at the root of so many of our most urgent modern problems.

A specially interesting and important group of the parasites that affect us are those that use man himself as the base of their own food pyramid. These are the organisms that prey on man directly and by their activities produce disease or even death. They are of the same general kinds as those that cause diseases of plants, though fungi are less conspicuous as parasites of man than as parasites of plants. From the geographer's point of view, one of the most interesting things about these organisms that attack man is their natural history and the ways in which they are transmitted from one man to another, because it is here that the relations between them and the diseases they cause, on the one hand, and the physical environment on the other, are most clearly seen.

Some disease-producing organisms are carried from man to man by direct contact, like those producing the venereal diseases, and others by droplet infection, as when we broadcast hundreds of germs of influenza or cold-in-the-head by an ill-regulated sneeze. These do not live long enough apart from man to be much affected by external conditions, though the cold of the Polar regions seems to be too much for some of them; however, the effects they produce may vary with external conditions. Colds and influenza, and many lung troubles due to infection by some sort of living organism, show a regular increase in this country in the cold damp months of winter and decline in importance during the summer. Larger parasites of man, such as lice, which are also transmitted directly from one person to another, because they have a very delicate constitution and cannot live long away from the particular conditions of humidity and temperature met with on the human skin, also show little direct relation to physical geography.

Some parasites, however, do not pass directly from man to man, but spend a part of their time living free on the earth, like hookworm larvæ, or in the dust of floors, like fleas. These are subject to geographical controls during their free-living stage. Fleas, for instance, do not like low atmospheric pressures, and so are absent from the mining camps of the high Andes and presumably also from Tibet. Hookworm larvæ can live only

in moist soil, and can only grow fast enough to bring about any serious infestation of the population if the temperature is high, at least 70° F. Below this temperature they grow so slowly that their chances of surviving long enough to be able to infect another man are very much reduced. Hence Hookworm disease, a form of anaemia which has a most debilitating effect on mental as well as physical energy, is almost confined to the wet tropics and to countries like Egypt where the temperature is high and the ground is kept moist by irrigation. The effects of Hookworm disease, particularly on mental development, are remarkable and distressing. Much of the backwardness and lethargy of the Poor Whites of the American South, symptoms known familiarly as the "Lazy Sickness" or the "Big Lazy," has been proved to result from heavy hookworm infestation, and when the parasites are eradicated great improvement follows in the mental alertness, physical activity and standard of living of the people affected. But hookworm has so far been suppressed in comparatively few of its haunts, and it remains one of the big problems confronting administrators seeking to improve the lot of poor and illiterate tropical peasants. "This one disease," says the Fourth Annual Report of the International Health Board, "where the infection is practically universal, may go far towards explaining the retardation of backward peoples." Since hookworm-infected peoples are also tropical peoples, because of the temperature and moisture requirements of the hookworm in its free-living stage, this parasite must be regarded as a prime agent in slowing down the advance of tropical natives towards higher levels of material culture. In the wet Tropics man has not only to contend with a climate that discourages mental and physical activity, as we saw in Chapter III, but also with diseases due to parasites of a peculiarly insidious and pernicious kind, that sap his mental as well as his physical powers.

Another, and an extremely interesting, group of organisms that attack man and cause disease are those which, in their passage from one man to another, make use of an alternate host instead of living free in the open. The malaria parasite is one

of these. It lives a part of its life in man, in the uniform physical and chemical conditions of his bloodstream, but before it can be transmitted to another man it must first be sucked up by a mosquito, in the body of which it undergoes a series of transformations and is subject to all the varying temperatures and other vicissitudes of the environment where the mosquito dwells, before it can develop to the stage at which it can infect another man when the mosquito bites him. Yellow-fever germs similarly live both in man and in a mosquito; sleeping sickness in man and nagana in cattle, in man or cattle and in the tsetse fly; bubonic plague, in man and in rat fleas, and so on. Some of these disease-producers may also live in other mammals besides man; the plague bacillus, for instance, gives plague to rats as well as to men. Bovine tuberculosis thrives in cows and may infect a child that drinks the cows' milk; certain loathsome parasitic worms live in pigs and can infect men who eat the pork, if it is insufficiently cooked; others live in dogs, and may be conveyed to a man if the infected dog licks his hand. The distribution of diseases such as these thus becomes extremely complicated to explain, because the different hosts of the parasite may be differently affected by certain geographical controls; also the parasite itself may be affected directly by them when in the alternate host, especially if it is cold-blooded creature such as an insect; and finally, the parasite, as happens with malaria, may be carried by different species, called "vectors," in different parts of its range.

As an example to illustrate some of the complexities that result from this state of affairs let us briefly consider malaria. Malaria, like hookworm, is a disease of the Tropics and sub-Tropics, because of the climatic requirements of the malarial parasites, tiny protozoa of several species of *Plasmodium*. Like hookworm, too, it is not a lethal disease, at any rate among populations that have had the opportunity to build up resistance to it, but it causes anaemia, lethargy, and a despondent and unambitious state of mind. Each of the different species of *Plasmodium* gives rise to a different type of malarial fever, and each has slightly

different preferences in temperature, but they are all quite capable of existing together in one place, or even in one person. Then to add to the difficulties there are many different species of mosquitoes of the genus *Anopheles* which can act as vectors, and even within one species some strains will act as vectors and others, superficially identical, will not. On the whole, however, the *Plasmodium* needs high air temperatures, over 70° F. at least, and preferably well over 80° F., if it is to develop fast enough to get through the part of its life-cycle that is passed in the mosquito before the mosquito dies of old age, and the mosquito also needs high temperatures if it is to breed fast enough to spread the disease widely among men; it also needs water in some form, either rainwater puddles, marshes, ponds or streams, because it lays its eggs and its young larvæ live in water. But its tastes vary with the species and even with different strains within a species. Some anopheline mosquitoes, as in the south of the United States, prefer stagnant water; others, as in the Philippines, prefer running hill-streams; some like their water brackish, as did the ones that used to carry the "ague" of Holland and the English Fens; others like it fresh, and so on. Then, too, further complications arise when we study the effects produced in different places when people are bitten by infected mosquitoes. In the wettest parts of the hot Tropics, in the Amazon and Congo basins, for example where malaria is very strongly entrenched and all the physical conditions are in its favour, there is little obvious sign of it in the body of the population, no serious epidemics and few deaths due directly to malaria except among new-born infants. Here, all the people have been heavily infected again and again from their earliest youth; by degrees, if they survive, they arrive at a *modus vivendi* with their parasites, and become so permanently resistant from repeated reinfection that a few hundred bites more or less from infected mosquitoes make little difference to them. But they are permanently anaemic, and suffer from the depression, inertia, and disinclination to think or act vigorously that malaria brings in its train. This lugubrious state of affairs, in which malaria is

said to be hyperendemic, prevails in damp climates where the mean temperature never falls much below 80° F. all the year round, with the interesting exception of many of the Pacific islands, where there are no suitable mosquitoes to act as vector for the parasite.

To the north and south of this belt of hyperendemic malaria, which encircles the globe near the equator, are two belts of epidemic malaria. Here the temperature rises to the required heights for a part of the year only, during the summer, when also the rains fall; in the cooler dry winters mosquitoes and cases of malaria disappear together. In these belts malaria is apt to occur in seasonal epidemics, during which half the total population may be laid low with fever at one time, till there is scarcely anyone left while the epidemic lasts fit enough to till the fields or tend the cattle. These epidemics follow the summer rains, when the vector mosquitoes breed in millions and are ready to reinfect everyone again from the bottomless reservoir of parasites left in the blood of the people from previous years. During the dry season, with no reinfections, the resistance of the population falls, and so reinfection by the busy mosquitoes in the wet season produces very marked symptoms; it is in these epidemic belts that malaria accounts for most of the three million victims a year that it kills in India and Pakistan alone.

In so short a space as this it is not possible to mention in any detail more than just one or two of the hundreds of organisms which prey upon man. Malaria and hookworm have been chosen for several reasons. Owing to their curious life-histories each of their causal parasites is at some stage directly subject to geographical controls such as temperature, and so their distribution is correlated with climate in a way that particularly appeals to the geographer. They are also, it would seem, very old diseases, probably as old as man himself, because they have learnt so well how to live in equilibrium with their environment. An unskilled parasite kills its host and thereby destroys itself; malaria and hookworm weaken but seldom kill. For this reason they are responsible for much of the backwardness of the

tropical peoples whom they hold in subjection, a backwardness which the enervating climate of the regions where they flourish does nothing to remove. In all schemes for the betterment of tropical peoples diseases such as these are one of the first things that need to be taken into account, since only by eradicating them can the peoples concerned be made fit enough mentally and physically to help actively in working out their own salvation.

Here, then, in the work of the pests and diseases that prey on man, his animals or his crops, we see yet another facet of the great complex of relationships between man and his physical environment which we set out to study in this book. In all the relations between man and other living species, as man by taking thought weighs down the balance of numbers in his own favour, so surely does he help some other, generally undesirable, living things to increase too: the pests and vermin that he hates because they rob him, blight and shrivel his crops, eat his stored grain, attack his cattle, and even weaken and hamper man himself. As surely as men and their crops increase, so do plagues and pests. Some, but not all, of these plagues and pests we know how to control, but in the final reckoning the cost of control may be as damaging as the ravages of the pest; there is a limit beyond which even man cannot go in his struggle with these organisms, for though science gives us every reason to hope that we shall be able to control them all in time, economics tells us that the cost of control may well rise higher than the savings effected through its use. The pests, in fact, have learnt how to engage in economic warfare. They, and the losses due to them are so universal, and their effects upon the distribution and yield of crops, and even upon the numbers and activities of men, so marked, that they must be taken as much into account in the study of Economic Geography as the simpler factors of climate, soil and relief: we must, in fact, pay attention not only to the inanimate but also to the animate physical environment. It is in this field that biogeography plays an auspicious role in linking together physical and human geography.

CHAPTER XII

CONCLUSION

HERE, then, we come to the end of our short and incomplete survey of some of the relationships existing between man and his environment. I said at the beginning that you must not expect to teach yourself from this book a great many facts, but only a point of view. The facts are all about you, to be had for the trouble of getting them, in the first place by observing and recording those that lie all around you in your own home region, and in the second place, for more distant parts of the world, by reading and by studying good maps. In this concluding chapter I shall say a little about how you are to acquire these facts and what you are to do with them when you have them, or in other words how you are to use the habit of mind that I hope you have taught yourself by reading this book, the habit of looking on no single phenomenon as existing independently of others, and of thinking of effects as well as causes when you look at what is going on in the world about you. Scientists spend most of their time seeking out causes of things; it is for us geographers, who are humanists as well as scientists, to seek the effects of things as well.

How, then, are you to set about becoming an active, practical Biogeographer? Having got your point of view, how are you to get the facts on which to exercise it?—and, it might be as well to add, how are you to know which facts are worth collecting and which are not? And when you have the facts, what are you to do with them?

How are you to get your facts? Let us deal with that question first. You must begin by teaching yourself to notice, and to record what you notice: you must learn to acquire the same habit of observation that a Boy Scout has to acquire. That advice sounds much simpler to follow than in fact it is: learning

to notice things is a process that needs years of training, and even when you have become really observant you can still go on for the rest of your life increasing your powers of observation. You will find plenty of good advice on how to learn to notice things in Boy Scout books and in the Sherlock Holmes stories, but here are some tips which may be more directly useful in learning to notice the facts of Geography.

Begin training yourself seriously, if you can, when on a holiday in a new place, or even when out just for a day's excursion. It is much easier to notice new things than things which you have seen every day for years, and the process of learning to notice them is so fascinating that it will immensely increase the pleasure you get from your holiday. If possible, begin at a country or seaside place, not in a large town: when you have cut your geographical teeth on a small and fairly simple area you can begin on something really difficult like a big industrial city or a whole county. Buy yourself a good large-scale map of the district: the new Ordnance Survey maps on the scale of 2½ inches to the mile are excellent, but if you cannot get one of them for the place you want the 1-inch to the mile maps will do instead; if you are going to work on a small region in great detail get the appropriate sheets of the 6-inch to the mile map as well. A geological map, on however small a scale, is most valuable: so also are the Land Utilization Survey maps now published by the Ordnance Survey. Get yourself a notebook with hard covers and if possible with a pencil or pen attached, and if you can afford it get a small camera. A ruck-sack to put things in when you go off for the day, and a bicycle to get about on if you want to cover a lot of ground, or a pair of stout shoes if your plans are less ambitious, complete your outfit.

Now what are you going out to look for? The facts of man's relations to the physical environment. That is an accurate but very dull way of putting it: let us put it into plain English. You are going to find out where and how people live, in the piece of country you have chosen; how the places they live in and the ways they make a living have been influenced by the physical

geography and in their turn have influenced it; what uses people have made of natural resources such as water, rocks and timber, and whether they have used them well or ill, constructively or wastefully; whether, in short, your chosen region shows good examples of harmonious relations between man and nature, or not.

Begin with the simple physical geography. You have the relief of the area on your map, but, whether or not you have a geological map as well, you must learn to know rocks and the soils derived from them in the field. Look for places where the underlying rocks are likely to be exposed; sea cliffs are excellent, but river cliffs, cuttings made for roads or railways, quarries, gravel pits and brick pits are all good and informative. Dig out bits of the rock, and compare the clean unweathered faces of the fragment with the exposed weathered one. Try to identify your rocks, both from the map if you have one and from books of reference, or, better still, by comparing them with actual named specimens such as you may perhaps find in a local museum. Learn to distinguish boulder clay from other kinds of clay such as the Gault or the Oxford Clay, and glacial sands from sands deposited by rivers or by the wind. The book in this series on Physical Geography will help you with all this. All the time that you are hunting your specimens in cuttings or quarries, and learning to notice and know your rocks, look also to the general landscape under which your rock lies: is it high land, or low valley, or plain; pasture or arable; heath, moor, down or woodland?—is the soil pale, red, brown, or black, and can you see clearly from the soil what kind of rock it was that made it?—is the view wide and open, or blocked with hedges and trees?—what kinds of trees, crops and other plants are there? Identify the crops, and if you are really keen on learning to train your powers of observation, learn also to identify the plants typical of certain kinds of soil, which you will find named in Tansley's *Types of British Vegetation*. To do this you will need one of the many good floras that are to be had nowadays: I prefer Gaston Bonnier's *British Flora*, helped out by Bentham

and Hooker's *Illustrations to the British Flora*, because then you can paint the plants as you find them into the illustrations, which are uncoloured woodcuts, and that is a great help to learning them thoroughly. Then also, while you are learning your rocks and soils, look out for examples of the local rock used in buildings, as suggested in Chapter IV. Take photographs of the buildings—or if you have no camera make sketches of them, to show how the stone is used—and put these in to amplify the descriptions in your note book. In the same way take photographs of the kinds of scenery which you are discovering to be typical of different kinds of rock, and use these for illustrations too.

Now here is a second important point: as you teach yourself to know the rocks and the soils they give rise to, the relief and the sort of landscape they produce, and the plants that are characteristic of them, *you must note everything down.* Recording observations is the best way of all of teaching yourself to notice things. It is not so much that you tend to forget what you have noticed if you do not write it down; that does happen, and is very annoying indeed, but that is not the main reason that recording observations is important: it is necessary to record because only by recording things are you really driven to notice them in detail, just as you only learn things thoroughly when you have to teach them to somebody else. You can record in words, or by drawings; photographs are pleasant to have, and very useful for certain things, but are not so valuable for teaching you to observe. In order to draw a thing or to describe it accurately in words you are obliged to study it carefully in detail, and when recording it in these ways you pay far more attention to it than you do when you just take a snapshot of it. Try it for yourself. Sit down with a notebook and make a careful outline sketch of the Chalk Downs, or the Snowdon country, or a strip of beach with cliffs. Even if the resulting sketch is quite hideous, you will find that in the process of drawing it you have learnt an astonishing amount about the landscape that you had not until then noticed. If you despair

of your artistic talent, set about the much more exacting task of writing a full description of what you see in words. You will not only learn a great deal about the landscape; you will learn a great deal about the language too! Try to set down, in one or other of these ways, all the things you notice about, say, the scenery characteristic of limestone, or granite, or the site of a town or a village, or the view from a prominent hill; it will immensely repay you for the time spent by teaching you what a lot there is in a landscape merely to *see*, that the ordinary casual observer misses entirely.

As a geographer, you have open to you yet another way of recording things of this kind, and that is by means of a map. Whenever you make a careful study of a landscape, write in, on the right place on your map, a few words about what you have noticed: invent symbols, if you like, for the special things you are working at and want to record (but do not forget to make a clear note in the margin of what your symbols mean). You will soon find that your observations begin to hang together in all sorts of unexpected and interesting ways, and the study becomes more and more fascinating the further you advance.

So far I have dealt only with the rocks and the relief, the easiest part of the physical geography to observe in the field. You cannot observe *climate* for yourself on a short holiday, though you can observe weather, since, as the child said, "Climate lasts all the time and weather only a few days." For the climate of a place you must turn to books of reference, such as Bilham's *Climates of the British Isles* and *British Rainfall*, published annually by the Meteorological Office.

Now you are armed with sufficient information about the environment to begin to turn your attention to man, though in fact you will find that you notice and record facts both of the physical geography and of the human activities of your region simultaneously once you are in the field. Many of the facts of human distribution and activities are already on your map—roads, villages, towns, isolated farms, railways, reservoirs and so on. You must amplify this information from your own observations.

In farming country, for instance, find out how the land is used: what is the type of farming practised, what rotations are used, what animals are kept, and for what purpose, what are the most important crops, how the labour is spread over the year's work, and so on. Read the local paper and talk to farming people: try to get some insight into the farmers' problems in that district. Look for advertisements on fences and barn walls of farm sales—and go to one: look for notices of produce or cattle markets in the local paper—and go to one; find out where the buyers and sellers come from, what is the catchment area of the sale, so to speak, and what produce is bought and sold. Make it a point of honour—since you are teaching yourself to observe—never to ask questions until you have entirely failed to find out what you want to know by just looking for it; this adds to the fun of the game. You will be astonished to find out how much your eyes will teach you if you firmly keep your tongue quiet. However, there are lots of important things that you can learn by talking to people which you cannot expect to learn by simple observation. And if, as you go along, you keep careful records in notebooks and on maps of all that you learn, you will find unexpected patterns beginning to emerge, unanswered questions beginning to crop up, and the subject becoming more and more interesting the further you delve into it.

Here I must enter a word of warning. Do not be misled into confusing facts of observation with theories about their causes. It is much easier to do this in practice than it sounds. You notice, let us say, that farms A and B lie high on chalk uplands, farm X on clay in a valley. You notice also that farms A and B are mainly arable, with few animals: farm X is a dairy farm. These things are facts of observation; there can be no argument about them. But if you are tempted to state in your notebook "The clay lowlands seem to suit cattle better than the chalk uplands," or something like that, you are confusing theory with fact. It may be that the farmer who runs farm X is a new arrival in the district, used to cattle in Dorset where he came from four years ago, and he is running a dairy herd on land that is not

really well suited to cows because he does not like farming without cattle. Or perhaps farm X belongs to one of the big dairy firms in a town fifty miles away, whereas farms A and B do not. Never generalise about causes from a small number of examples; it is a temptation to which geographers are peculiarly liable and to which they too often succumb. Be warned in time. But when you have enough observations of localised distinctions of this kind to warrant a broad statement of fact about them, when you have examined all the farms in the district and have plotted their activities on a map, you can justifiably say, as a *fact* and not a theory: "Whereas only 20 per cent of the farmers on the chalk keep cattle, 90 per cent of the valley farmers do so." When you have accumulated a set of facts of this sort, it is also permissible to try to find out from the farmers themselves why they do certain things instead of others that their neighbours do; the answers you will get to your questions are likely to cure you of making over-hasty generalisations.

What I have been saying applies, of course, to other industries and activities besides farming; to anything from the fishing and seaside lodging-house industries that you may meet on your holidays, to heavy industry, textile manufacturing and so on. But these more complex and artificial industries of recent growth often show little relationship to simple physical factors and are much more closely related in their location and practices to economic and historical factors than to purely physical ones. If you are to tackle them satisfactorily, begin by learning some Economics, and by reading the books in this series on Economic Geography and on Historical Geography, and teach yourself the habit of observation on the simple lines suggested in this chapter before you begin.

So far, in getting your facts for yourself, you have done little more than any ordinary text-book of regional geography will do for you. You have observed the natural features and resources of the region, and have seen what man makes of them. Now a great deal of this, once you have learnt to notice it, is extremely obvious and a matter merely of commonsense. It is common-

sense to build your house of the rock that you can quarry out of your own hillside, or thatch it with reeds from the local fen; to build a dam across a steep narrow valley instead of a flat wide one; to use light sandy soil near a town for growing fresh fruit and vegetables, or to set your house in a pleasant sheltered spot near a good spring. Observing all this is instructive, and much increases your power of appreciating a landscape for more than its picturesqueness, but it does not really take you very much further. To describe a landscape or a region simply in terms of the uses man has made of the natural resources that lie to his hand is akin to describing a bird from a stuffed skin in a museum, or a plant from a greenhouse specimen in a pot. The thing is dead, in the sense that it is cut off from its natural surroundings and unable to act in its customary way; you can observe its attributes but not its actions. This static approach to the study of all the regions of the world will be found in many older books on geography and indeed in many modern text-books as well. The authors of these books appear to assume that their job is simply to describe with a vast wealth of detail just how man has adapted himself to the prevailing geographical conditions and has used the available natural resources for his own ends, and that once they have done that they have done their geographical duty by that particular region; the specimen is described, classified and fitted into its niche in the general scheme. I hope that if you have read this book you will consider that, to the Biogeographer, a regional description of this kind is only half finished; it is a description of a dead specimen instead of a living one. Not until you have considered the region in action, as it were, as a living organism not only passively acted upon by its physical environment but itself actively affecting that environment, an organism in a state of continual change fulfilling specific functions and producing specific effects among its surroundings, will you have studied the region in the way truly characteristic of a Biogeographer. So this is your next job: to look for the results as well as the causes of human actions in your chosen region.

Consider water first, because it is a problem everywhere. Find out how the isolated farms, the villages, towns, factories and the cattle in the fields get their water; how sites of houses and settlements are related to natural sources of water (the volume in this series on Historical Geography will help you here): or how they have had to adapt and redistribute the natural supplies of water to fit in with their particular needs. This is all a simple matter of how man uses his natural resources. But now look further, for the effects that he has thereby produced on the environment. Go to look at the local water-works, but look at the local sewage works too. The text-books and guide-books all tell you how Manchester gets its water from the Lake District or Birmingham from Wales; how many of them tell you where that water is poured when it has been used, or what it is like when it enters the Irwell or the Rea? How many pay any attention at all to the effects of the redistribution of water on the streams from which it is taken, or on the rivers into which it is fed? Go and look at your local sewage outfall; talk to the people who live near it; if you are holidaying in a seaside town, go and look at the harbour water at low tide, or take a boat and row past the local gasworks or the local foundry; I think you may be dismayed by what you find.

This is only one example of the sort of effect I mean; it is a particularly easy one to observe almost anywhere. But there are others equally obvious in some places, if you have trained yourself to notice and to think about what you see: the effects produced by mining on the countryside range from sterile, weed-grown spoil-heaps to subsided areas with houses askew, drains and sewers disrupted, and floods in wet weather; industry, besides the enormous changes it produces in the landscape and in the distribution of people, may affect vegetation and even types of farming through polluting the air with chemicals and soot, and it uses water on an immense scale and often with little regard to any but economic values. Talk to the farmers on the town outskirts, and to the officials of local angling clubs, and you will learn a lot about this subject.

In this country, where we draw our food so largely from overseas, soil erosion is not a serious problem, except on a small scale in a few places; our own agriculture is reasonably conservative, except under the heavy pressure of war-time needs, and you will find that its effects are beneficial rather than harmful for the most part. It is not so easy to notice beneficial effects as harmful ones, because they show themselves in such things as increases in output of crops or yield of dairy cows, and to find these out you need to study blue-books and returns of all kinds on the lines suggested in the book in this series on Economic Geography. You may find, however, some evidence that man's farming activities are altering the distribution of the soil water; many rural districts complain nowadays of falling water tables, with wells getting lower and yielding less (though this may be due to many other causes, such as increase of population, action of town water-works, and so on, as well as to the use of the land). However, in many places you can see for yourself dozens of dead or dying trees in the hedgerows; when all allowances have been made for the ravages of disease and storms, the lack of labour to dispose of dead timber during the war years, and so on, there are still many trees that appear to have died recently from no very obvious cause; since they are often only partly grown, they cannot have perished from old age, and the frequent presence of deep drainage ditches close beside them lends colour to the idea that they may have died from lack of water around shallow roots. This may be advantageous in other ways, but it suggests a problem for the Biogeographer to follow up.

If you ever go abroad, to the drier parts of Europe around the Mediterranean or in Spain, or to any continent outside Europe, you will find abundant material for studying the results of different farming methods in different climates, and may find plenty of evidence of faulty soil usage shown by soil erosion. Chapter IX will give you some idea of what to look for.

Here then is an answer to the first question we asked: How are you to get your facts?—and in answering it I have at the

same time answered in general outline the second question: How are you to know which facts are worth collecting and which are not? The true answer to this question is that it is impossible to tell; until you have observed everything you can about a region, or an industry, or a town, or what you will, you cannot tell what its problems are, and you will often find after you have patiently observed and recorded all relevant facts that the real problems are quite different from what you expected. If you had at the outset a preconceived idea of what the problems were likely to be, and let this idea in any way influence your observations, you may find that you have to do a lot of your fact-finding again. Start with a completely open mind, merely looking for what William Dampier called "observables," and letting the problems appear and the questions shape themselves as the facts accumulate.

Now to our third question: What are you to do with the facts when you have got them? If only for your own satisfaction, I should recommend you to set them down in writing as clearly as possible, in the form, say, of an article for a local paper or a magazine. There need be no idea of ever publishing them, and they may indeed be far from welcome to a harassed local editor, but setting your observations down in this way is an excellent training in picking out what is and what is not relevant, and in marshalling your facts. It shows you where you have failed to obtain facts that you need. It is also very instructive to go back later to what you have written, when you have improved in observation and in insight into the facts and problems of Biogeography. And if you should ever happen on an example of serious misuse of natural resources, such misuse as arouses your crusading instincts, you will have at your disposal an excellent weapon for attacking abuses, by stirring up and educating public opinion, if you have learnt how to set out your facts and your arguments clearly and forcibly. Your self-training in recording observations will stand you in good stead here; so will the book in this Series called *Teach Yourself to Write*.

So much for the concrete results of what you may have learnt from this book; let us turn now for the last page or two to the less tangible ones.

Geographers are not much more likely than politicians to be able to point the way to reforming the world and to retrieving some of the muddle and mess that we have made of it, since we took to subduing nature instead of submitting to her. But they can contemplate our odd vagaries in a more detached spirit than can the man whose job it is to devise immediate measures to meet immediate needs; biogeographers are especially interested in the curious creatures that may come to light beneath the stones that the politicians and administrators are not leaving unturned, and in the vistas likely to appear from the avenues that they so diligently explore. It is the geographer's duty to search far horizons, and to call attention to the probable long-term results of actions which on a short-term view may have much to recommend them: there might have been no Dust Bowl had the High Plains farmers, making their rapid fortunes from wheat in the early years of this century, paid more heed to academic voices prophesying woe.

The Biogeographer has his own special contribution to make to the solution of some of our most pressing modern problems, because he appreciates perhaps better than a politician how many of our troubles have come upon us simply by reason of our simplest biological needs, and how our instinctive actions to satisfy these needs may set in motion a complex series of changes in the dead physical world and the living world of plants and animals that surrounds us. Nature seldom works quickly, and she often reacts so slowly to man's aggressive treatment of her that we think she has been unaffected by it, and that we have conquered her; it may be years or decades before we begin to realise that, far from being conquered, she is fighting back, and with the weapons that wound us most deeply in these days, our own economic weapons. The money cost of our victory over her mounts steadily, till we may begin to wonder whether it was really a victory after all. We know this all too well in our wars

with our fellow-men; why do we never expect it in our wars with nature?

If we are not ourselves farmers, or seamen—or Biogeographers!—we forget how much a part of nature we still are, and how she still controls the sources of our most fundamental necessaries, food and water. Bemused with our own technical skill, we convince ourselves that we can do all things, and forget that though we can split the atom, fly with the speed of sound, and converse familiarly with men in the Antipodes, we have still no power to make seeds grow or the rain fall. All these things we have made for ourselves—how many of them do we need as we need water and food? If they were all to vanish overnight only those of us would perish also who, like ourselves in this island, have come to rely so much on artificialities that we can neither eat nor drink without them. I said in Chapter II that man was physically an unspecialised animal and that thereby he was freed from the chains of the environment that shackle highly specialised animals. But in the western world he has scorned the freedom that nature left him, and has bound upon himself, ever more and more securely, stronger chains of his own forging, chains of deliberate specialisation for a town life. Birds and bats cannot live unless they can fly through the air to seek their food; if their wings are broken, they die. How much are town dwellers in this country better off than they? Cut our water pipes, destroy the ships that bring us food from overseas and the trains and lorries that distribute it, and what is left us? Millions of us now are fully as dependent for our very lives on artificial transport services as the bat is on its wings. Instead of the physical specialisation that nature has spared us, we have submitted ourselves to an economic specialisation of our own making. Presumably the bat, who is proverbially blind, neither notices nor cares to imagine any way of life that differs from his own; this is also, unfortunately, all too true of many town people, who fail entirely to realise that their way of life, right, proper and desirable as it appears to them, is in fact an over-specialised, parasitic growth, absolutely depending for its

nourishment on the rural societies that they ignore or despise, and on the transport systems that have grown up along with the towns, the man-made arteries through which their life-blood flows.

It is my hope that this book may help a little to teach those who read it something of the truth of our relations to the earth: she is still our mother, though we neglect or maltreat her, and though patient, she is stern. Let us teach ourselves to work with her, not against her, to be grateful for her gifts and use them well, for only when we have made our peace with earth will there be goodwill among men.

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